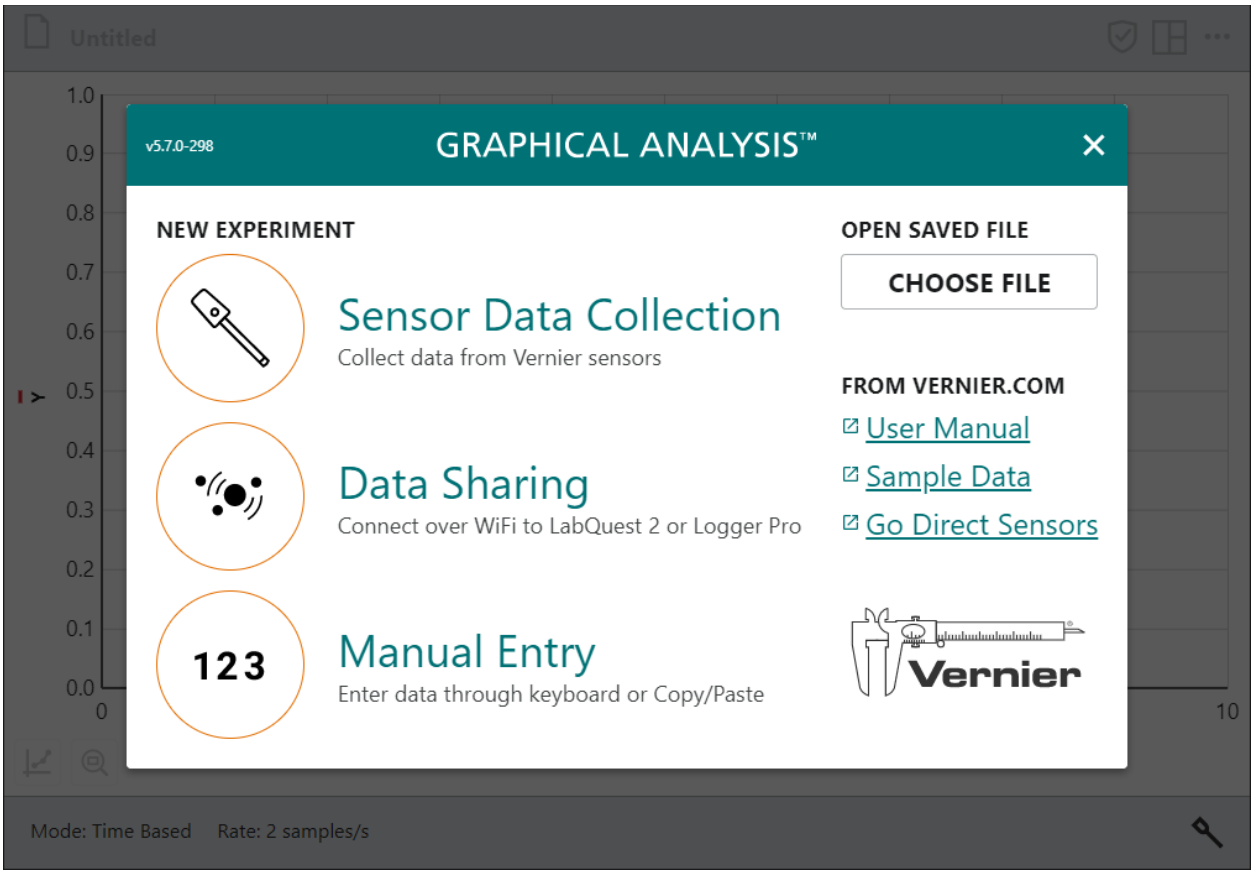
Vernier Graphical Analysis™ and Graphical Analysis Pro—User Manual



Version 5.7.1
April 2021

ABOUT THIS GUIDE

The Vernier Graphical Analysis and Graphical Analysis Pro User Manual is an extended guide detailing the features of the Graphical Analysis app both with and without the Graphical Analysis Pro features unlocked. This guide can be used with any platform-specific version including the versions for Windows® and macOS® computers, Chromebook™ notebooks, and iOS, iPadOS® and Android™ devices.

This document reflects features available in Graphical Analysis version 5.7.1.

CONTENTS

CHAPTER 1—GETTING STARTED WITH GRAPHICAL ANALYSIS

I. Downloading Graphical Analysis

Download Graphical Analysis from the Vernier website or the appropriate web store.

- Windows and macOS computers—download from the Vernier website
- Chrome computing devices—download from the Chrome Web Store
- iOS and iPadOS devices—download from the App Store
- Android devices—download from Google Play

For up-to-date system requirements, visit www.vernier.com/graphical-analysis

Licensing Information

Vernier Graphical Analysis™

Graphical Analysis is a free app for Windows and macOS computers and can be installed on an unlimited number of computers.

Graphical Analysis is a free app for Chrome, iOS, iPadOS, and Android distributed through the respective web stores. Terms and licensing are thus determined entirely by these stores.

Vernier Graphical Analysis™ Pro

Graphical Analysis Pro is a set of subscription-based features that extend the functionality of the Graphical Analysis app. These features are licensed for use on devices owned or used by students and faculty of the K–12 school or college department that purchased the subscription. Transferring the license key to anyone outside the school or college department is prohibited.

Graphical Analysis Pro requires an installation of the Vernier Graphical Analysis app.

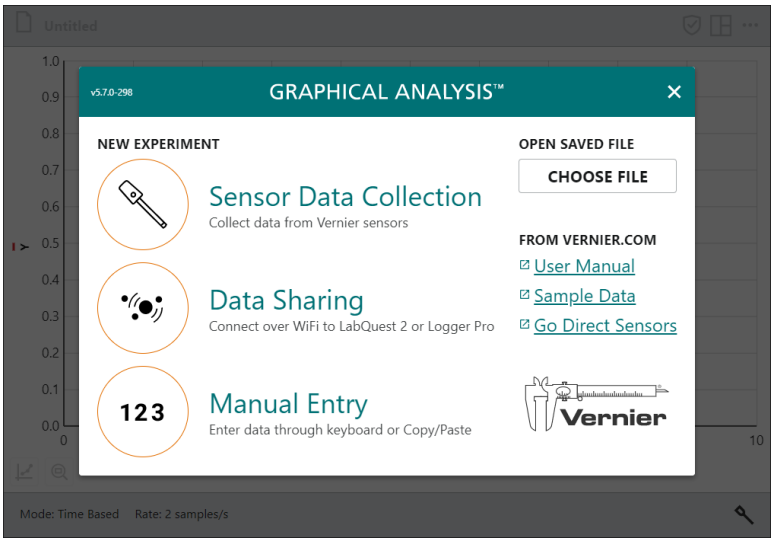
Privacy Statement

COPPA, SOPIPA, and FERPA Compliance

Graphical Analysis and Graphical Analysis Pro comply with federal regulations pertaining to student privacy and safety in the following ways:

- Graphical Analysis and Graphical Analysis Pro do not collect, request, share, or store any personal information from students or instructors.
- Graphical Analysis and Graphical Analysis Pro do not display advertisements in the app.

II. Launching Graphical Analysis for the First Time



When Graphical Analysis is launched without any sensors connected to your device, the New Experiment box displays. Choose which type of experiment you want to do.

Sensor Data Collection

Click or tap Sensor Data Collection to collect data from Vernier sensors. Supported sensors include the following:

- Go Direct® sensors connected via USB or Bluetooth® wireless technology
- Go!Temp® and Go! Motion® USB sensors
- Wired LabQuest® sensors connected via a LabQuest interface (Original LabQuest, LabQuest 2, LabQuest 3, LabQuest Stream®, LabQuest Mini, or Go!Link®)

***TIP!** If a sensor is connected via USB when Graphical Analysis is launched, Sensor Data Collection is automatically selected, and the New Experiment box is not shown.*

Data Sharing

Click or tap Data Sharing to set up Graphical Analysis to receive wirelessly streamed sensor data from a Data Sharing source. Data Sharing sources can be any of the following:

- LabQuest 2
- LabQuest 3
- A computer running Logger *Pro*® 3 software
- Graphical Analysis Pro*

* The Graphical Analysis Pro features must be unlocked to use this feature.

Manual Entry

Click or tap 123 Manual Entry to initiate an experiment in which you manually enter data into a data table. You can use Graphical Analysis to analyze non-sensor data that you collect, find in a textbook, or find on the internet.

Other Options

Open Saved Files

Click or tap CHOOSE FILE to open saved Graphical Analysis files (*.gambl or .ambl*) or comma separated value (*.csv*) files.

Sample Data

Choose Sample Data to access sample data files for Graphical Analysis. Sample data files include data for Boyle's Law, Ball Toss, Plant Transpiration, and Periodic Trends.

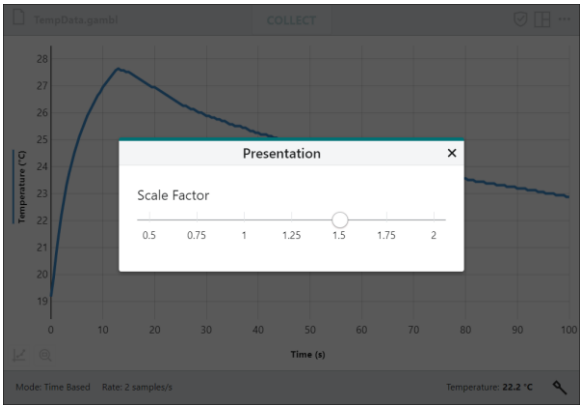
When the Graphical Analysis Pro features are unlocked, click or tap SEE EXPERIMENTS for access to additional experiment files. For information on unlocking the subscription-based Graphical Analysis Pro features, see Unlocking Graphical Analysis Pro Features in Chapter 8.

Modifying the Font Size with Scale Factor

You can modify the font size used in the app. This is particularly useful when presenting the app with a projector or viewing the app on a device with a high-resolution screen.

Click or tap Other Options, •••, on the top toolbar and choose Presentation to modify the scale factor used in Graphical Analysis.

***TIP!** Reduce the Scale Factor when viewing multiple graphs to see more detail on each graph.*



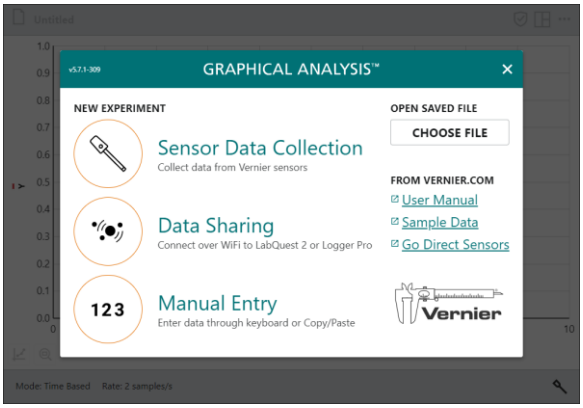
Unlocking the Graphical Analysis Pro Features

For information on unlocking the subscription-based Graphical Analysis Pro features, see Unlocking Graphical Analysis Pro Features in Chapter 8.

III. Quick Start to Sensor Data Collection and Analysis

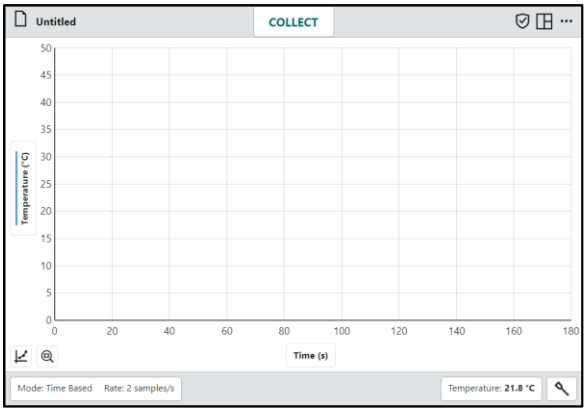
Follow these steps to quickly get started with basic sensor data collection and analysis.

1. Launch Graphical Analysis app.



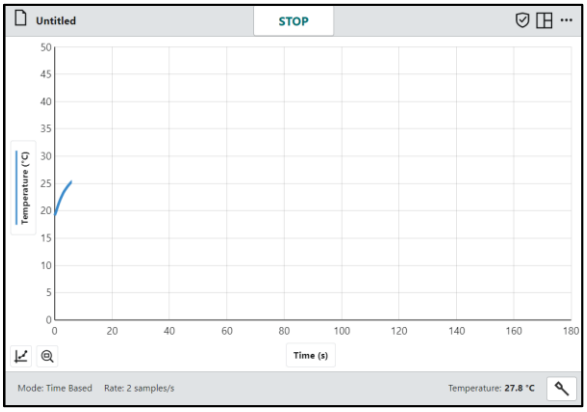
2. Select  Sensor Data Collection and connect a sensor. The default collection rate for the sensor is automatically set.

   For more information on how to connect a sensor, see Getting Sensors Connected to Graphical Analysis.



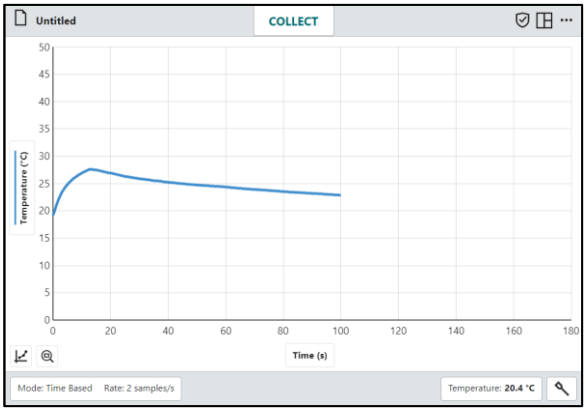
3. Click or tap **COLLECT**.

   TIP! *During data collection the Collect button,* **COLLECT**, *changes to* **STOP**.



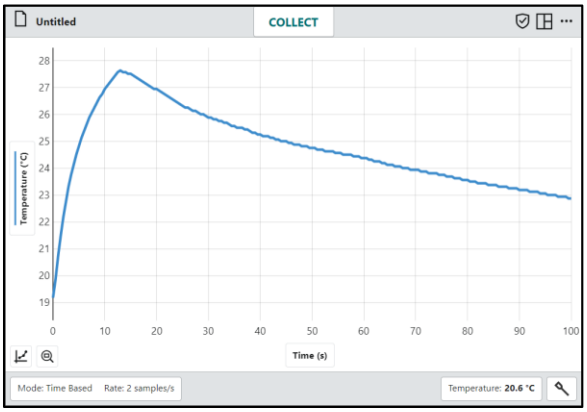
4. Click or tap STOP to manually stop data collection.

   TIP! *When collection ends or is stopped manually, the Stop button,* STOP*, changes back to* COLLECT.



5. Click or tap Zoom, , to scale the graph to fit the data.

   TIP! *You can also double-click or double-tap the graph to autoscale the graph to fit the data.*

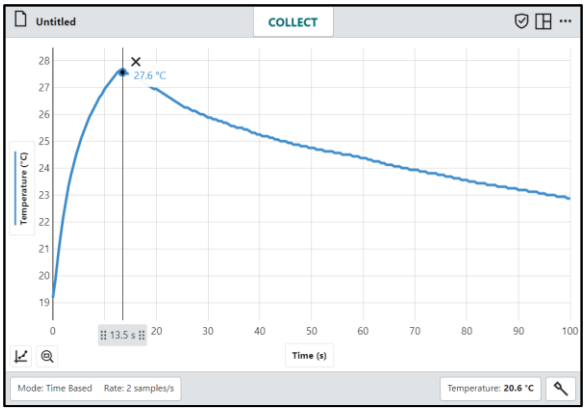


6. Click or tap the graph to examine a point of interest. The coordinates of the point are shown.

   Click or tap a different point or drag the Examine line to further examine your data.

   To remove the Examine line, click or tap Delete Examine Tool, ✕, displayed next to the line.

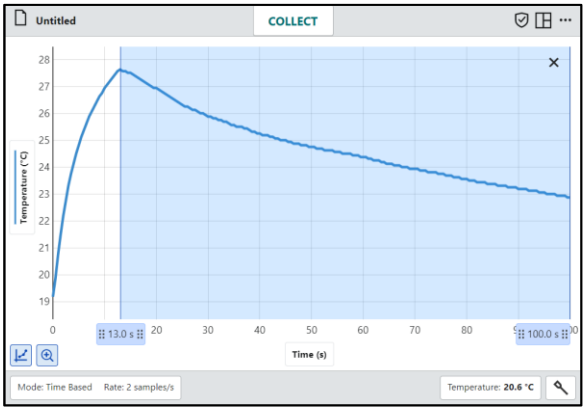
   TIP! *When viewing multiple graphs, the Examine line shows on all graphs.*



7. Click-and-drag or touch-and-drag across the graph to select a region of data for analysis. The selected region becomes highlighted.

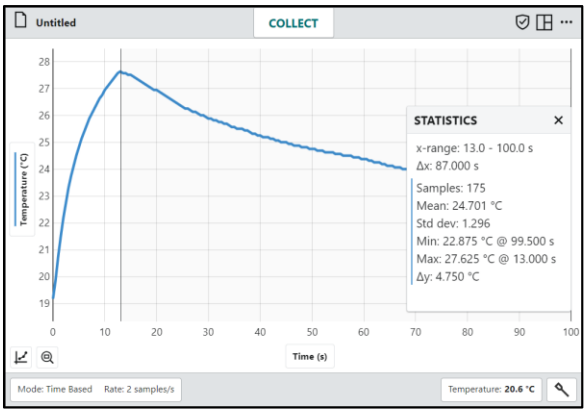
   - To modify a region, drag the edges of the region.
   - To remove a selection, click or tap Delete Selection, ✕, displayed on the region.

   TIP! *To analyze all data, you do not need to select a region.*

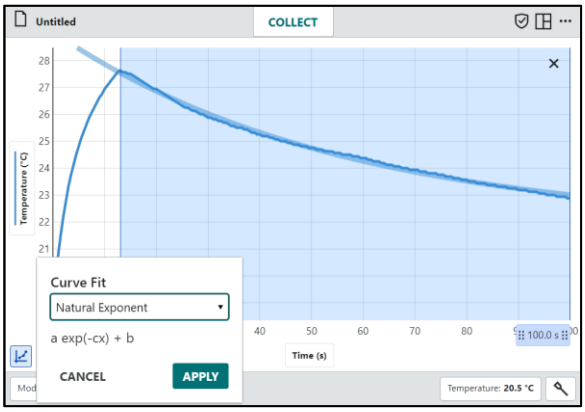


8. To view Statistics, click or tap Graph Tools, , and choose View Statistics. Statistics information is displayed on the graph.

   To dismiss Statistics, click or tap Close, ✕, on the details box.

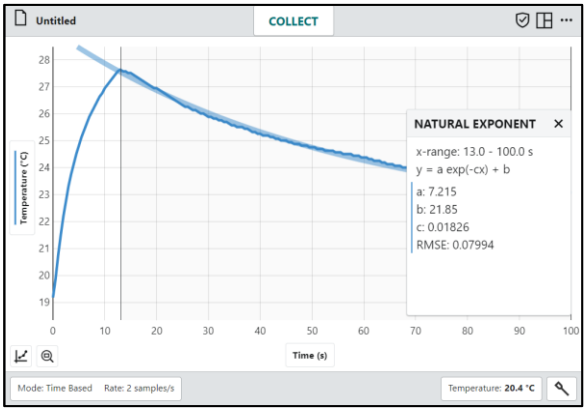


9. To fit a curve to the data, click or tap Graph Tools, , choose Apply Curve Fit, then select the desired fit equation. A preview of the curve fit is displayed on the graph.

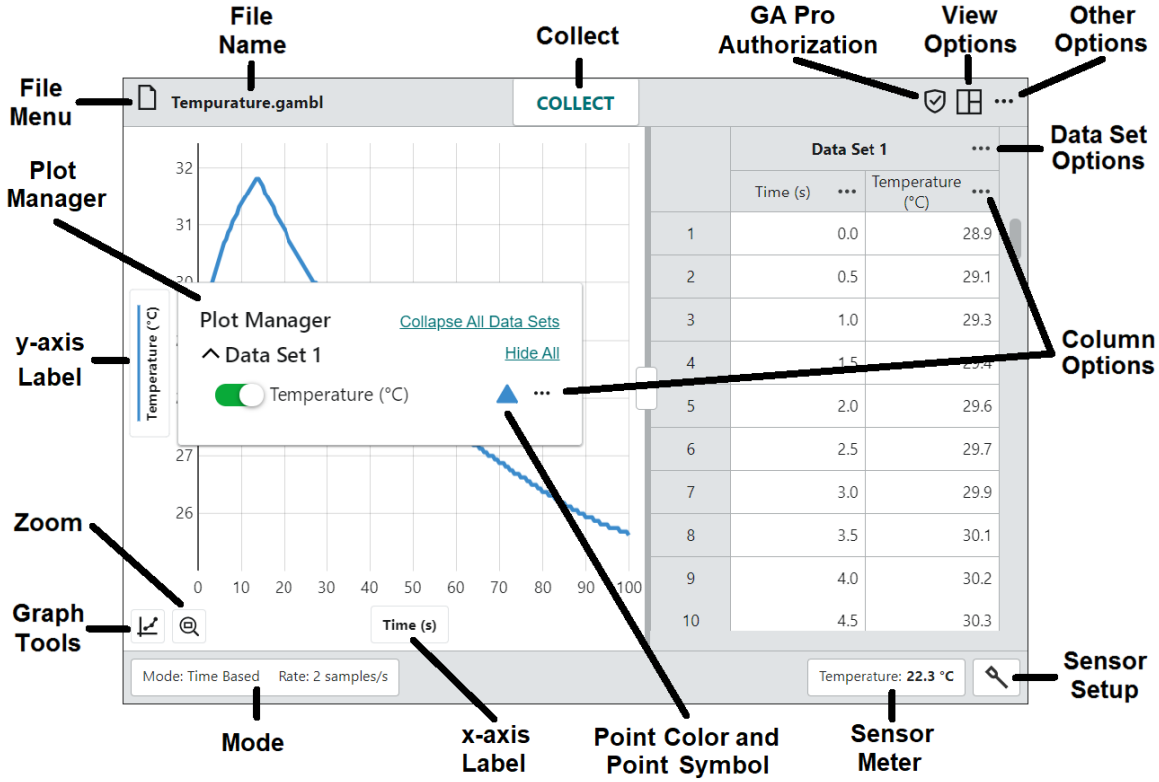


10. Click or tap **APPLY** to display the curve fit equation and coefficients on the graph.

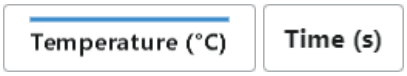
    To remove the curve fit, click or tap Close, ✕, on the details box.



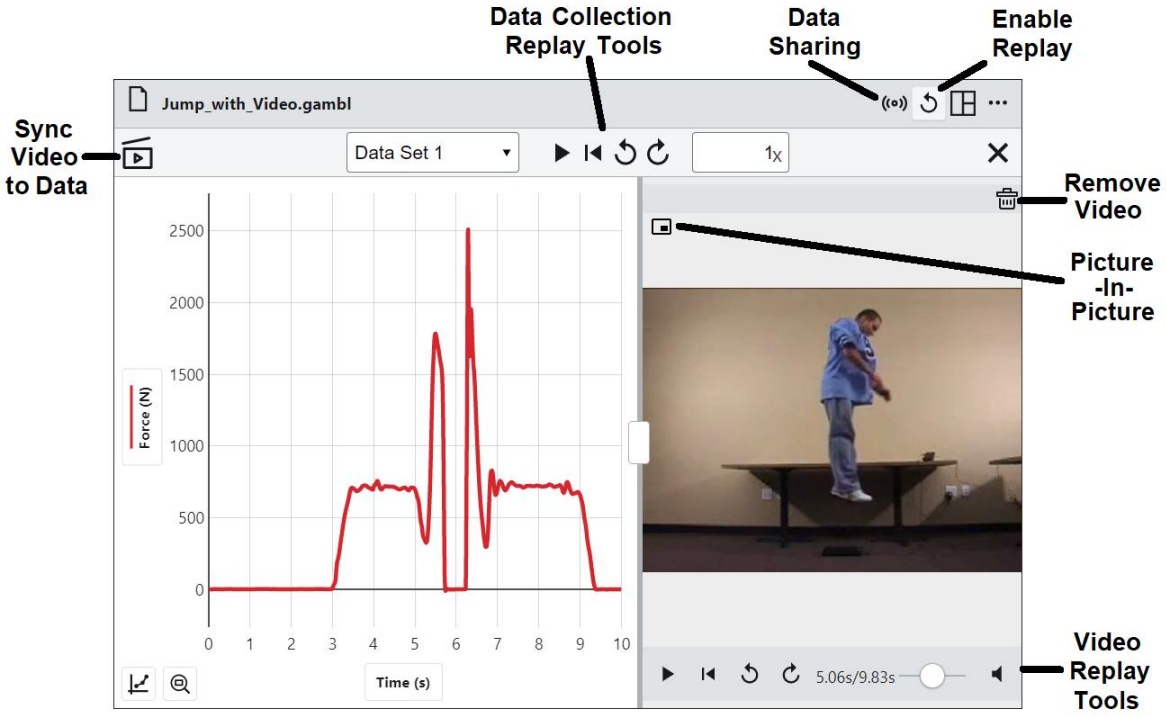
IV. Looking at the Graphical Analysis Tools

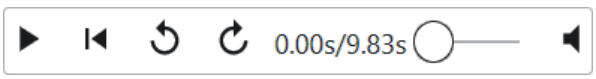


Untitled	Access the File menu to start a new experiment, open a saved experiment, save your work, or export graphs or data.
COLLECT	Start and stop data collection.
	Unlock Graphical Analysis Pro features.

	Adjust the view to include one or more graphs, a data table, or sensor meters. When Graphical Analysis Pro features are unlocked, you can also add a video.
	Access Other Options to modify the font and button sizes, access the user manual, and see what is new in the current version. When this icon is shown next to a column or data set name, click or tap the icon to access menu options specific to columns or data sets.
	Use the x- and y-axis labels to change what data are plotted on your graph.
	Customize the graph appearance by changing the default point symbol and/or the trace color.
	Access data analysis tools from the Graph Tools menu including curve fits, statistics, and integral tools.
	Scale your graph to zoom to all data or zoom to a selection of data.
	Set your data-collection mode and modify data-collection parameters such as rate and duration.
	Access a sensor meter for changing units and sensor calibration.
	Access Sensor Setup to view which sensors are connected, connect to wireless sensors, and modify sensor channels (select Go Direct sensors).

Graphical Analysis Pro Tools



	Host a Data Sharing session to share your data with other Graphical Analysis Pro users via the internet.
	Access tools to replay a time-based data collection including syncing a video of the collection to your data.
	Control the replay of data collection and synced videos.
	Synchronize a video of a time-based data collection.
	Control the replay of a video.
	Use picture-in-picture format to unclutter the Graphical Analysis Pro screen when videos are included. This feature is not available for all platforms and all operating systems.
	Remove video from the file.

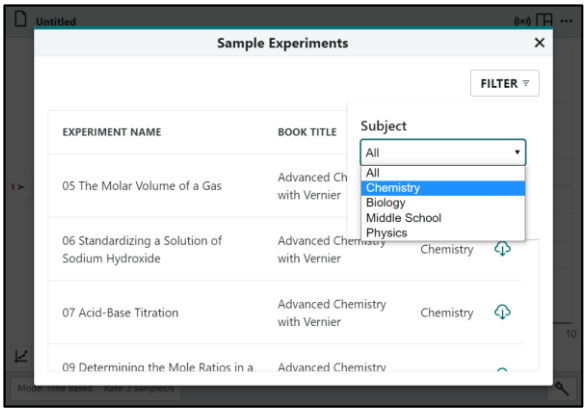
V. Summarizing the Graphical Analysis Pro Features

Below is a summary of the features available when you unlock the subscription-based Graphical Analysis Pro features. For instructions on how to unlock these features, see Unlocking Graphical Analysis Pro Features in Chapter 8.

Sample Experiments

Graphical Analysis Pro comes with over 40 sample experiments that include both data and videos. Use these files with your students for pre-experiment exercises, independent study, or post-experiment enrichment. Experiments for middle school, biology, chemistry, and physics are included.

TIP! *You can use these files as-is or use them for inspiration to create your own files.*

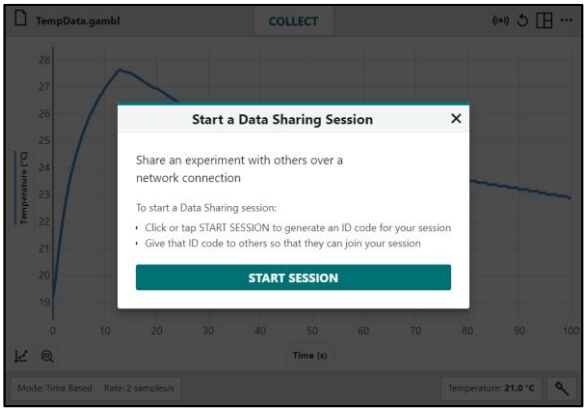


Data Sharing

You can use Graphical Analysis Pro as a data sharing source that streams sensor data to other devices running Graphical Analysis Pro.

Use Graphical Analysis Pro to data share lecture demonstration data with your in-person class or with students studying remotely so they can independently analyze the data.

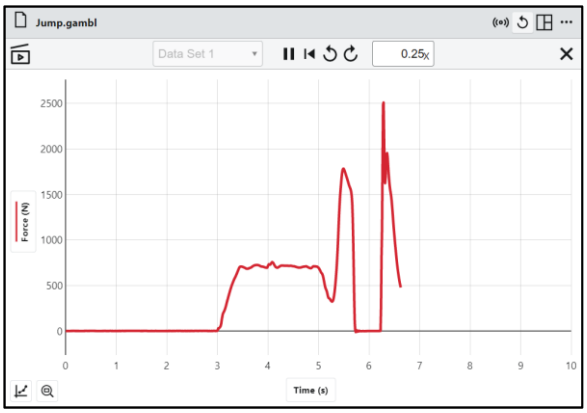
TIP! *This feature requires a live internet connection.*



Replaying Data Collection

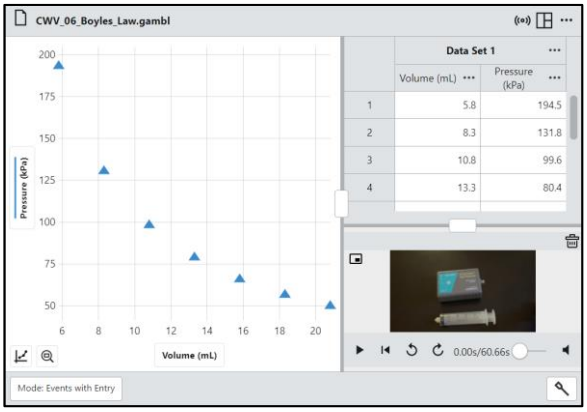
You can choose to replay a time-based data collection while having control over the replay speed.

TIP! *Pair this feature with a video of a time-based sensor data-collection experiment synced to your data for a powerful analysis tool.*



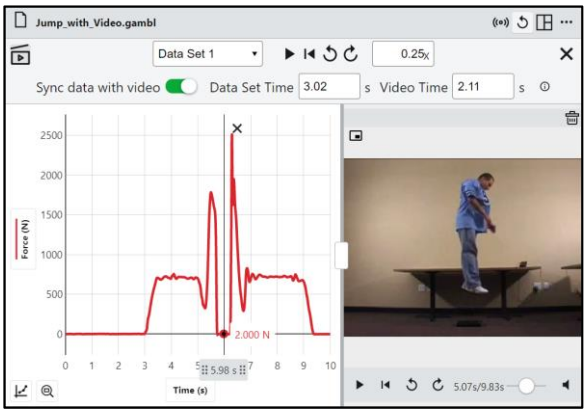
Adding Videos to Experiment Files

Add videos to your experiment files to illustrate how the experiment was done.



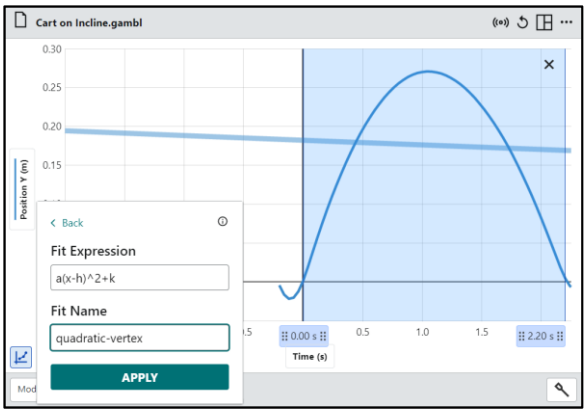
Syncing Video with Data Collection

Sync a video of a time-based sensor data-collection experiment for enhanced data analysis of your experiment. Replay the data collection to see how the action in the video correlates to the collected data.



Customized Curve Fits

You can create new curve fit functions to use to analyze your Graphical Analysis Pro data.

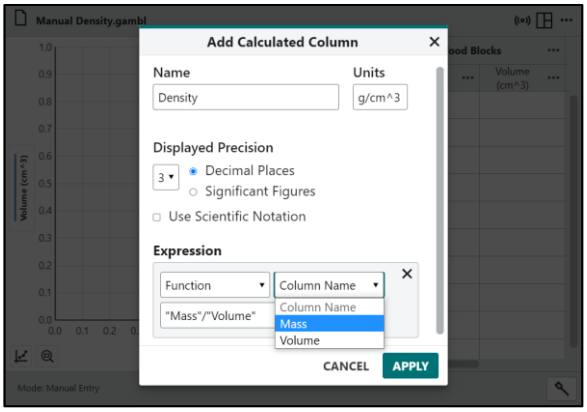


Here are some examples expressions:

- **Modified Linear**
  A+B*x **or** slope*x+intercept
- **Modified Quadratic**
  A(x–h)^2 + k **or** A(x–a)(x–b)
- **Base-10 Exponent**
  A*10^(Bx+C)+D
- **Gaussian**
  A*exp(–(x–B)^2/C^2)+D

Custom Expression Calculated Columns

Use mathematical functions to define custom expressions for your calculated columns in Graphical Analysis Pro.



Available functions include the following:

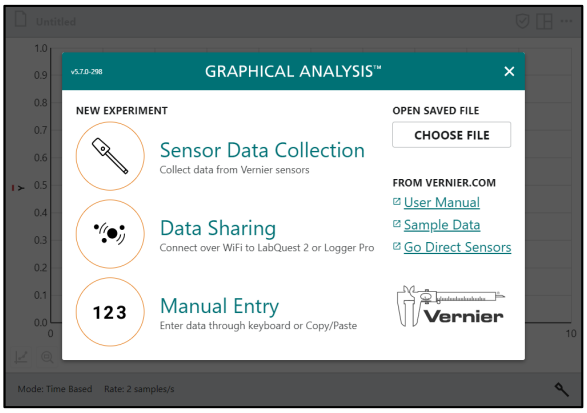
- Common math functions including square root, cube root, power, exponential, and logarithmic functions
- Trigonometric functions including inverse and hyperbolic trigonometric functions
- Number sense functions including absolute value, round, truncate, ceiling, floor, and modulo

For a complete list of functions, see https://www.vernier.com/til/11314.

CHAPTER 2—COLLECTING SENSOR DATA

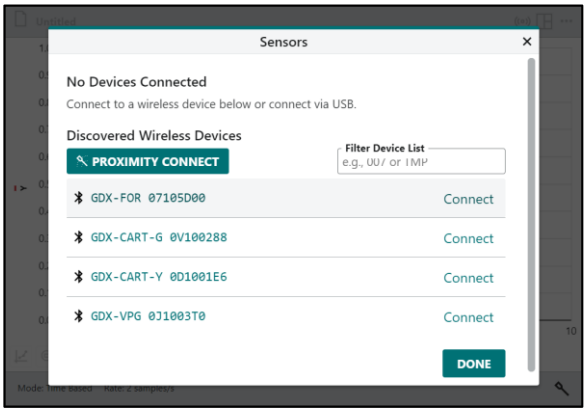
Launch Graphical Analysis to view the New Experiment box.

***TIP!** If Graphical Analysis is already running, click or tap the File menu, Untitled, and choose New Experiment. You may be prompted to save or discard the current file.*



Click or tap Sensor Data Collection to start a sensor data-collection experiment. This displays the Sensors box.

***TIP!** If a sensor is connected via USB when Graphical Analysis is launched, Sensor Data Collection is automatically selected, and the New Experiment box does not display. If this happens, click or tap Sensor Setup, , to display the Sensors box.*

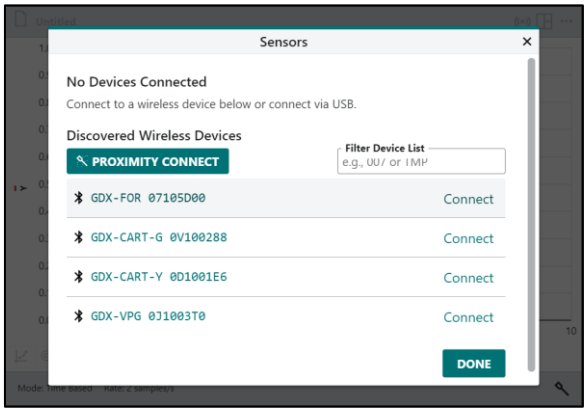


I. Getting Sensors Connected to Graphical Analysis

Connecting Sensors via Bluetooth Wireless Technology

Vernier Go Direct sensors can connect to Graphical Analysis using Bluetooth® wireless technology. The connection is one-to-one meaning that only one device (computer, Chromebook, smartphone, or tablet) can connect to that sensor at a time.

1. Make sure your sensor is on.
2. From the Sensors box, locate your sensor in the Discovered Wireless Devices list. The serial number, located on each sensor, represents the sensor name.
3. Click or tap Connect to connect to your sensor.



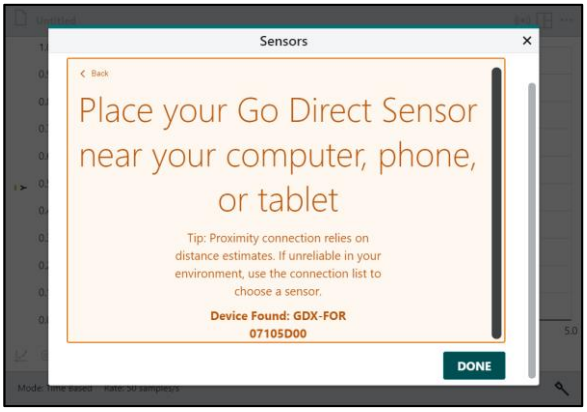
NOTE: Older Vernier wireless sensors—Wireless Dynamics Sensor System (WDSS), Go Wireless Temp, Go Wireless pH, and Go Wireless Electrode Amplifier—are not supported in Vernier Graphical Analysis. These sensors will not appear under Discovered Wireless Devices.

Tools for Finding and Connecting Your Sensor

Using Proximity Connect

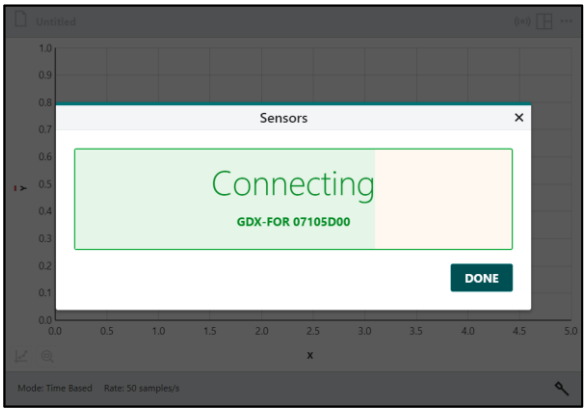
You can use Proximity Connect to connect to the sensor with the strongest signal. This is typically the sensor closest to your computing device.

Make sure your sensor is powered on and located near your computing device. Click or tap PROXIMITY CONNECT to initiate the automatic connection.

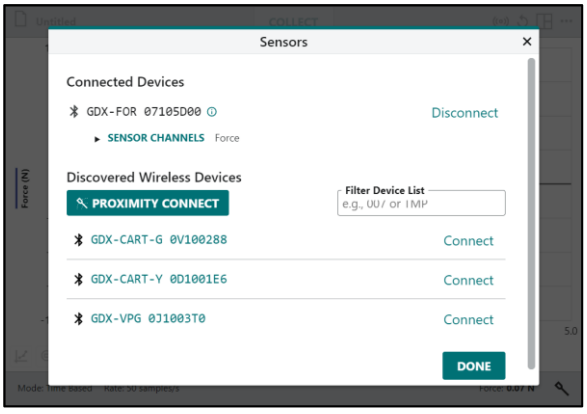


The sensor with the strongest signal is identified and connected automatically.

TIP! *Since many factors can affect signal strength, Proximity Connect may not always connect to the sensor closest to your computing device. If you have trouble connecting to the correct sensor, manually select your sensor from the list.*



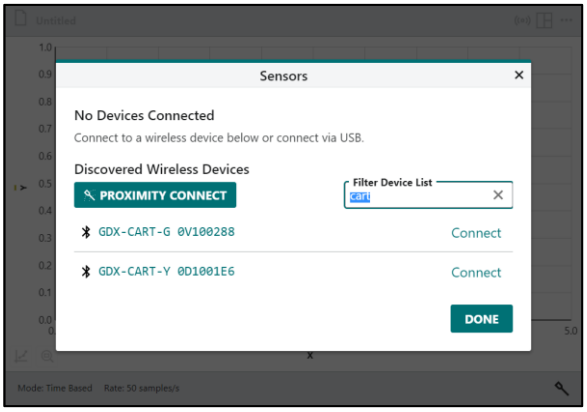
When using Proximity Connect, the app connects to one sensor at a time. You can repeat the process to connect additional sensors as needed.



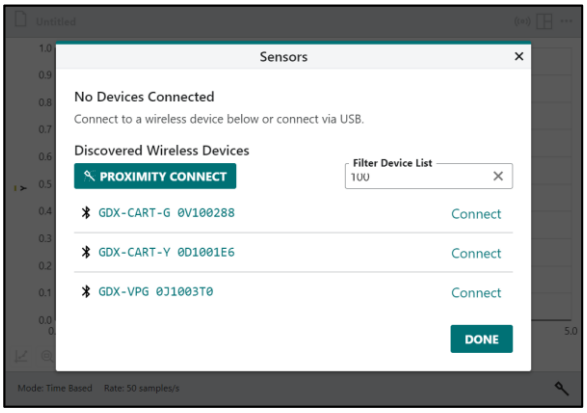
Using Device List Filter

Use the device filter to help locate your sensor in the list.

You can enter part of the sensor order code to look for all sensors of a certain type (e.g., type “cart” to find all sensor carts).



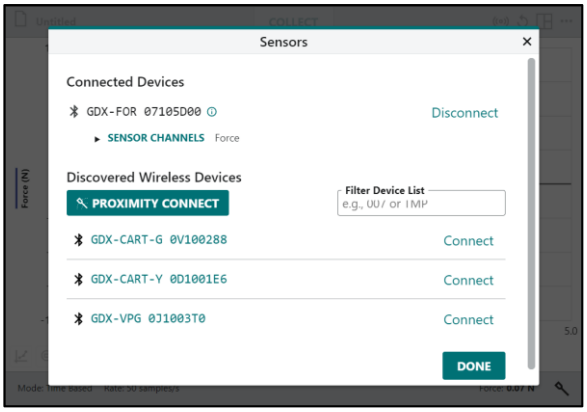
You can enter part of the serial number found on the sensor label to show only sensors with that particular character or characters (e.g., type “100” to find all of the sensors with 100 in their serial number).



Setting Up Sensors with Multiple Sensor Channels

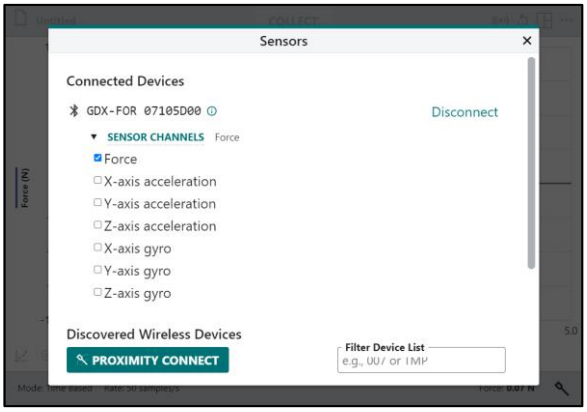
Some Go Direct sensors have multiple sensor channels. These sensors have default configurations that do not typically use all available sensor channels.

These sensors can be identified by the Sensor Channels details displayed under its listing in the Connected Devices list.

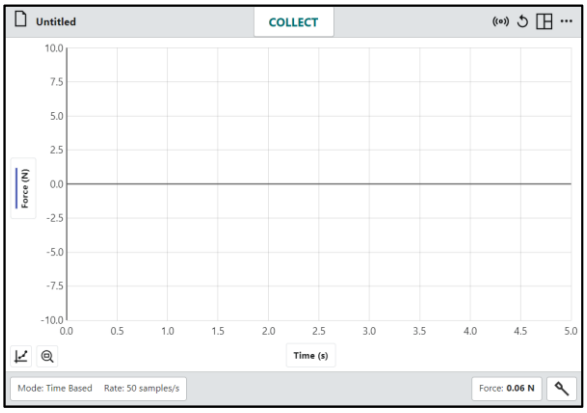


1. Click or tap Sensor Channels to modify the default sensor configuration.
2. Modify the sensor channel configuration as needed for your experiment.

   TIP! *For some sensors, selecting a new sensor channel automatically deselects the previously selected sensor channel. This indicates that those sensor channels cannot be used at the same time.*



3. Once you have connected to and configured the sensor channels as desired, click or tap DONE to continue with your experiment.



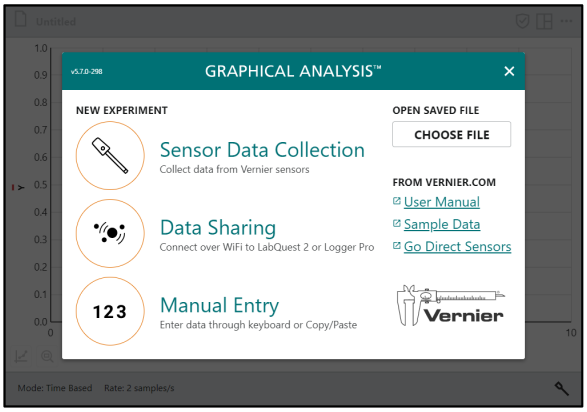
TIP! *If needed, you can click or tap Sensor Setup, [wrench], to return to the Sensors box, where you can add or remove wireless sensors and modify the sensor channel configuration of a connected sensor.*

Connecting Sensors via USB (Computers and Chromebooks only)

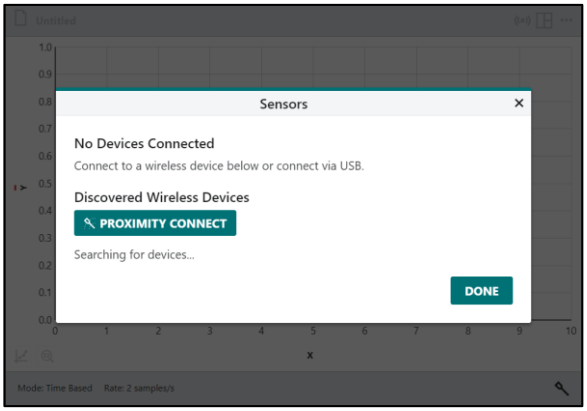
USB sensors, such as Go!Temp, Go! Motion, and our Go Direct sensors can connect to a computer or Chromebook for data collection with Graphical Analysis. You can also connect to Vernier wired LabQuest sensors when using a USB sensor interface such as a Go!Link, LabQuest Mini, LabQuest Stream, original LabQuest, LabQuest 2, or LabQuest 3.

1. Launch Graphical Analysis on your computer or Chromebook to view the New Experiment box.

   TIP! *If Graphical Analysis is already running, click or tap the File menu, [Untitled], and choose New Experiment. You may be prompted to save or discard the current file.*

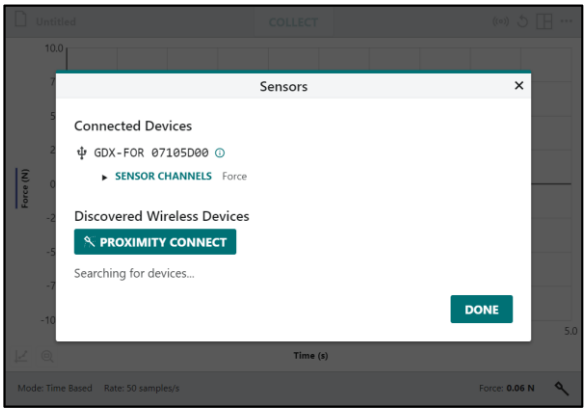


2. Click or tap Sensor Data Collection to start a sensor data-collection experiment. This displays the Sensors box.

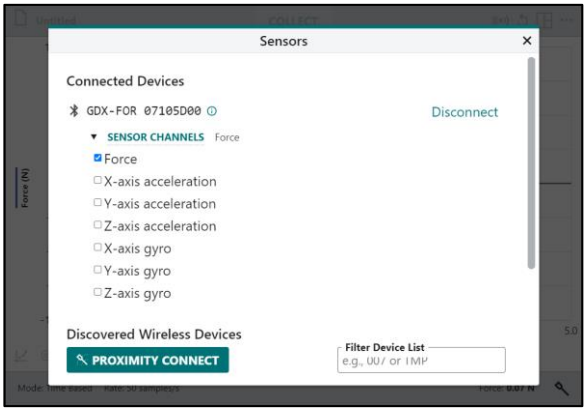


3. Connect the sensor to your computer or Chromebook™ notebook. (If you are using an interface with a wired sensor, connect the sensor to the interface, then connect the interface to your computer or Chromebook.)

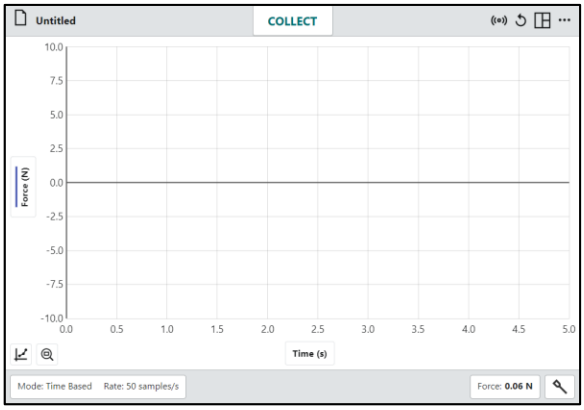
   TIP! *If a sensor is connected via USB when Graphical Analysis is launched, Sensor Data Collection is automatically selected and the New Experiment box does not display. If this happens, click or tap Sensor Setup,* , *to display the Sensors box.*



4. If your sensor is a Go Direct sensor with multiple sensors channels, set up the sensor channels as described in Setting Up Sensors with Multiple Sensor Channels.



5. Once you have connected to the sensor and configured the sensor channels as desired, click or tap **DONE** to continue with your experiment.



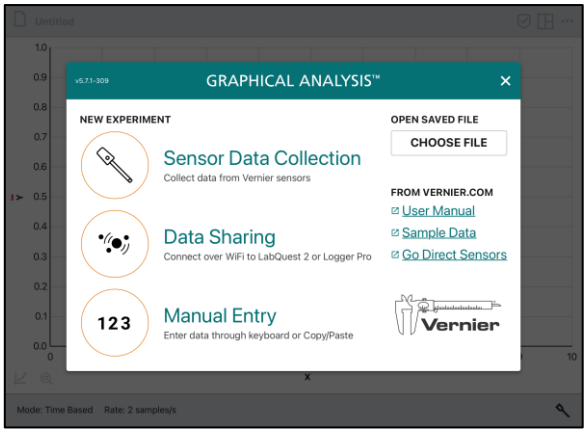
Note: Older wired sensors that require an adapter to connect to an interface and/or do not automatically ID when connected are not supported in Graphical Analysis.

Connecting Sensors via Wireless Interface (iOS, iPadOS, and Android Only)

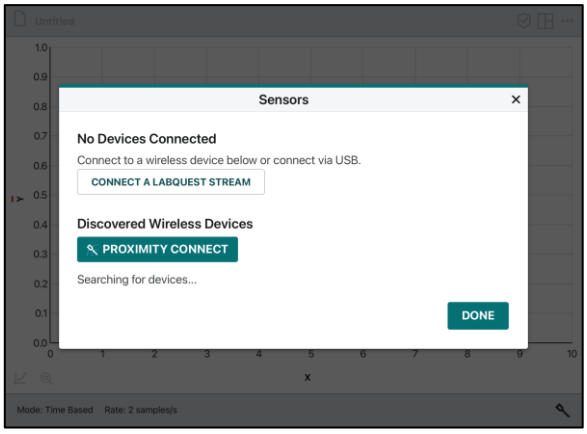
You can connect Vernier wired LabQuest® sensors to an iOS, iPadOS, or Android device using a LabQuest Stream® interface connected to your device via Bluetooth® wireless technology. This functionality is not supported on a computer or Chromebook as LabQuest Stream can only connect to those platforms via USB connection.

1. Launch Graphical Analysis on your device to view the New Experiment box.

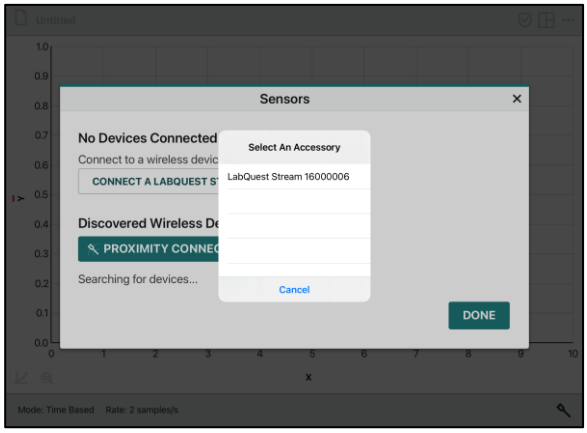
   TIP! *If Graphical Analysis is already running, click or tap the File menu,* **Untitled**, *and choose New Experiment. You may be prompted to save or discard the current file.*



2. Tap Sensor Data Collection to start a sensor data-collection experiment. This displays the Sensors box.



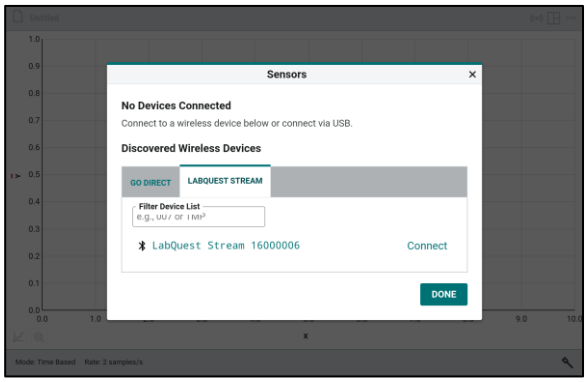
3. Connect the sensor to LabQuest Stream and power on the interface.



iOS and iPadOS Devices

Tap CONNECT A LABQUEST STREAM.

TIP! *It can take 30 seconds or more before the discovered LabQuest Stream devices are show in the list.*

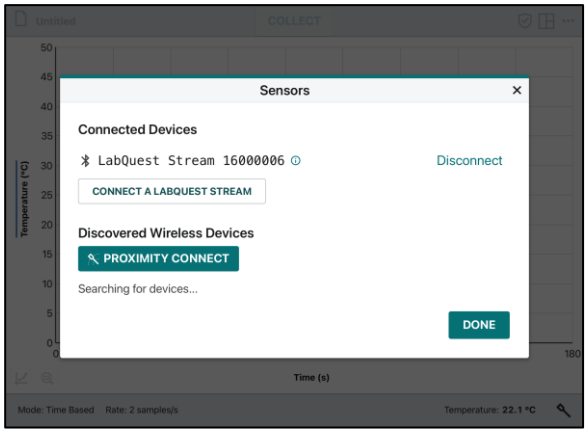


Android

Tap the LabQuest Stream tab.

TIP! *You can filter your list of discovered LabQuest Stream units if needed.*

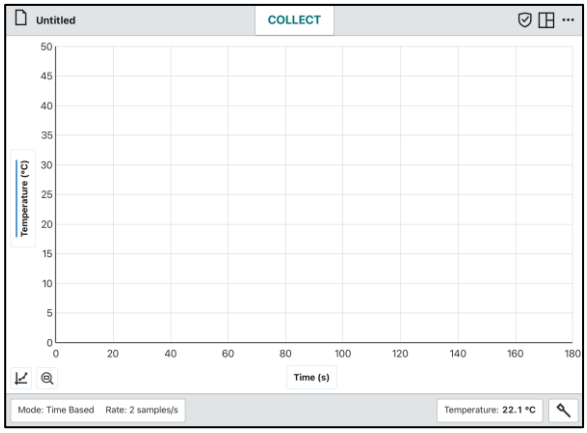
4. From the list of discovered devices, select your LabQuest Stream.



The LabQuest Stream serial number is used as the unique identifier for that interface. This number is found on the back label of the LabQuest Stream unit.

5. Tap **DONE** to continue with your experiment.

Note: Older wired sensors that require an adapter to connect to an interface and/or do not automatically ID when connected are not supported in Graphical Analysis.



II. Configuring Sensors

A digital sensor meter (e.g., Force: **0.00 N**) for each connected sensor is shown on the bottom bar of Graphical Analysis. The value shown is the current reading of a sensor updated about twice a second. These readings are based on the sensor calibration and can be configured as described below.

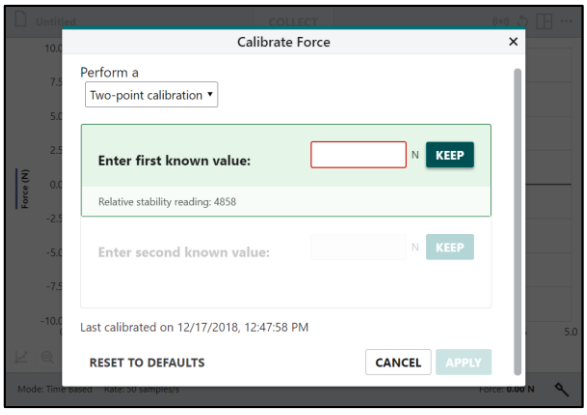
Click or tap a sensor meter, Force: **0.00 N**, to access tools that modify the sensor readings. The tools include options to calibrate, zero, reverse, and change units. Which tools are available depend on the connected sensor as not all options are appropriate for all sensors.

TIP! *These tools can also be accessed from the meters displayed using View Options,* .

Calibrate

Most sensors use a custom factory calibration stored on the sensor. However, some sensors require calibration. Choose Calibrate to initiate sensor calibration. Not all sensors can be calibrated.

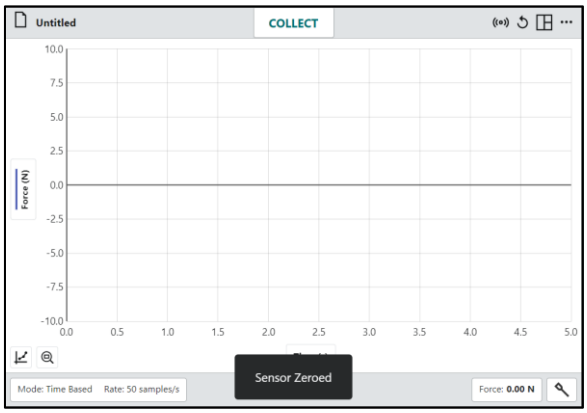
TIP! *Detailed calibration instructions are provided in sensor user manuals available online at* www.vernier.com/manuals.



Zero

Choose Zero to set the current sensor reading to zero. This defines an offset that is applied to all future readings. Not all sensors can be zeroed.

TIP! *Zeroing does not affect data that have already been collected.*



Reverse

Some sensors read both positive and negative values. For example, Vernier force sensors read positive values when pulled and negative values when compressed.

Turn on Reverse to swap the sign of the readings with respect to the default behavior. Not all sensors can be reversed.

TIP! *Previously collected data are not changed when Reverse is toggled.*

Units

Some sensors have the option to display data in different units. Choose the desired unit of measure from the Units dropdown menu. Not all sensors have additional units that can be selected.

TIP! *Choosing a new unit changes all existing and subsequent data for that sensor.*

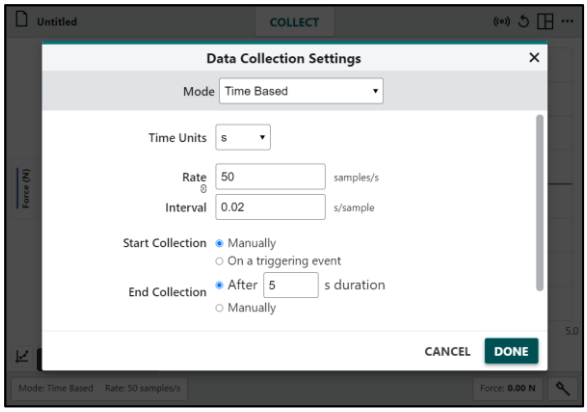
III. Modifying the Data-Collection Settings

Click or tap Mode, Mode: Time Based Rate: 50 samples/s, to open Data Collection Settings. The parameters listed depend on the connected sensors and the mode selected.

Mode: Time Based

Time-based data collection is the default data-collection mode for most sensors. In this mode, sensor readings are recorded at regular time intervals.

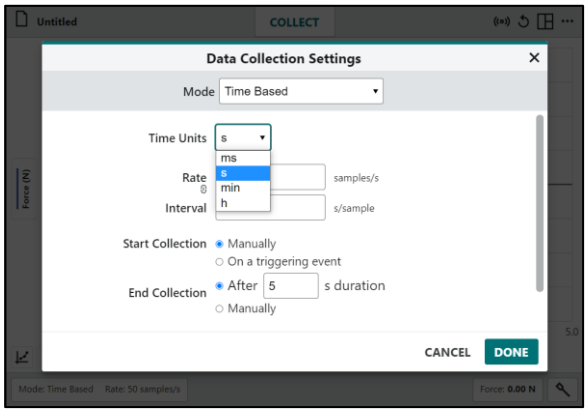
Parameters for this mode include Time Units, Rate and Interval, and Start and End Collection. The total number of samples to be collected based on these parameters is displayed.



Time Units

The default time unit is seconds. Additional time unit options include milliseconds, minutes, and hours.

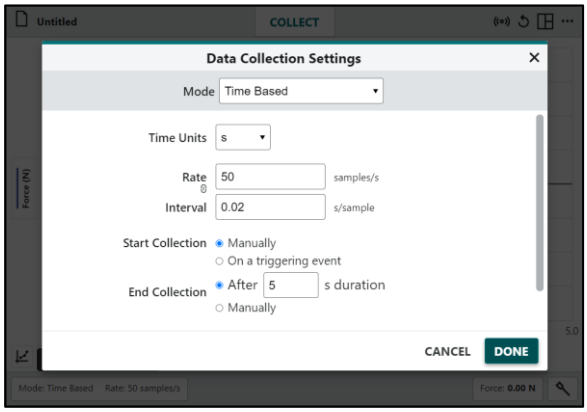
Time unit changes are applied to the rate, interval, and duration values as indicated by their units.



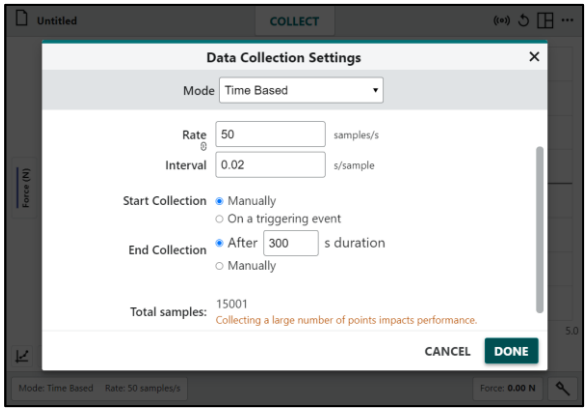
Rate and Interval

Rate refers to the number of data points collected each time period. Interval refers to the time period between successive data points. Changing one of these values automatically changes the other, as they are reciprocals of each other.

TIP! *When using multiple sensors, the fastest default collection rate for the connected sensors is used as the default rate.*



When the Rate × End Collection Duration exceeds 15,000 points, a warning is displayed indicating performance of the app may be impacted.

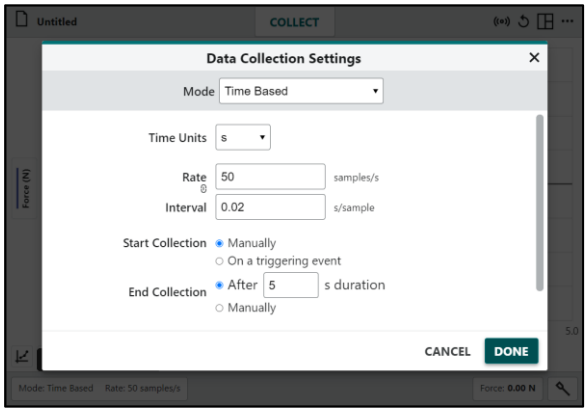


Start Collection

The two options for starting data collection are Manually and On a Triggering Event.

Manually

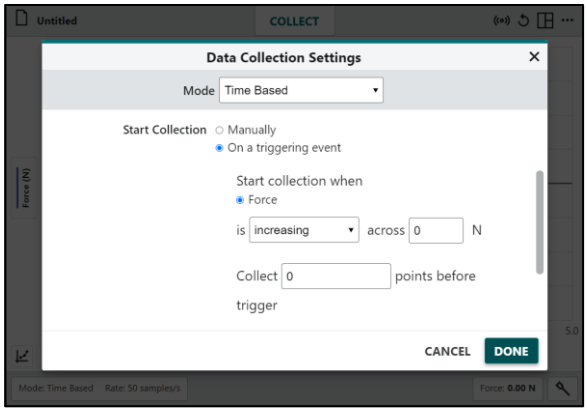
This is the default option that requires you to click or tap COLLECT to start data collection.



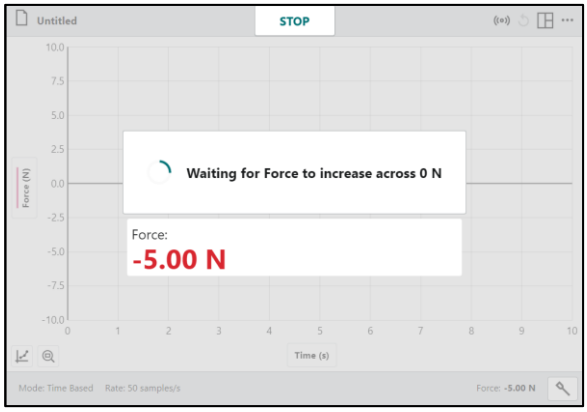
On a Triggering Event

When On a Triggering Event is selected, Graphical Analysis waits for a trigger threshold condition to be met before recording data.

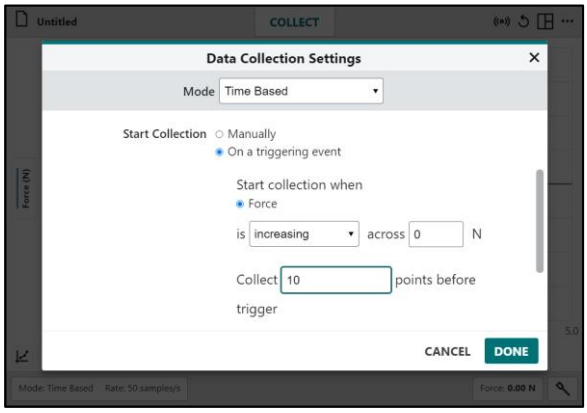
Choose the sensor used for the trigger and set the trigger threshold value. You can trigger as the sensor reading increases or decreases past the threshold value.



Click or tap COLLECT to start monitoring for the trigger. When the trigger condition has been met, data begin plotting on the graph.



You can choose to collect data points before the trigger condition is met. The time values for those points will be negative. Choosing this option will increase the overall experiment duration.



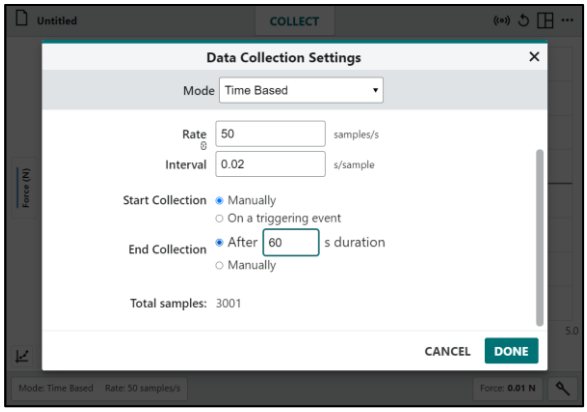
End Collection

There are two options for ending data collection—After Fixed Duration or Manually.

After Fixed Duration

Ending after a fixed duration is the default option. Data collection continues until the duration time is met.

The default duration is determined by the connected sensor(s) but can be modified. When more than one sensor is connected, the default duration is the shortest duration of the connected sensors.



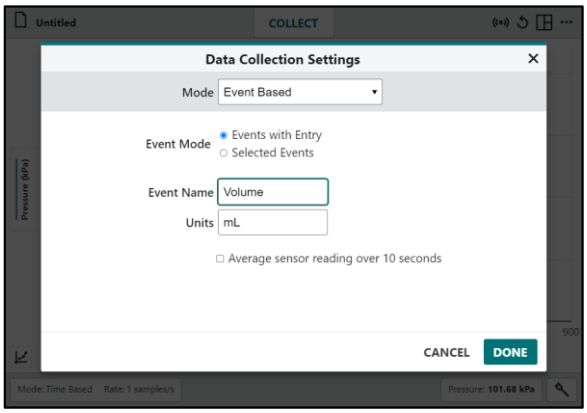
***TIP!** You can click or tap* STOP *to end collection early if needed.*

Manually

This option requires you to click or tap STOP to stop data collection.

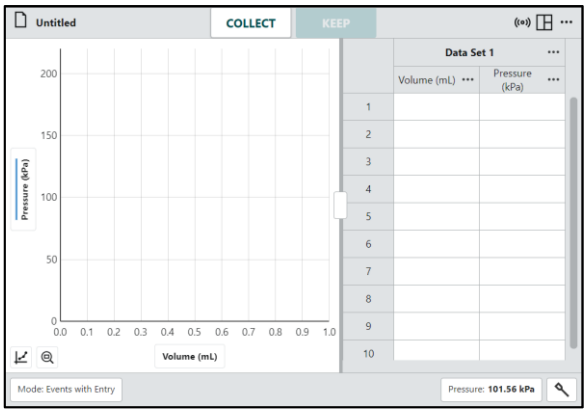
Mode: Event Based

Sometimes experiments use an attribute other than time as the independent variable. For example, in a Boyle's law experiment, you investigate pressure as a function of volume of a gas. For these situations, event-based data collection is used.



Parameters for this mode include Event Mode and 10-second averaging. You can also rename and provide units for the "Event" column.

The default view for event-based data collection includes a graph and a data table.

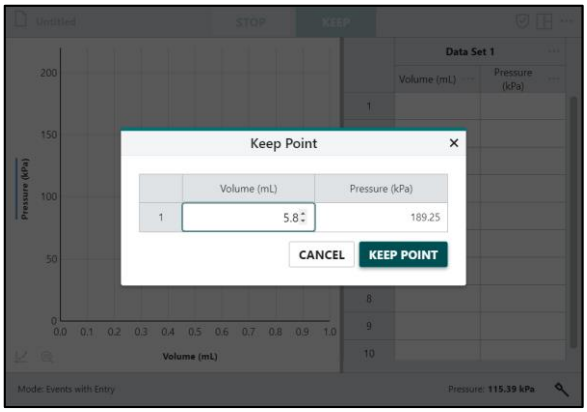


For event-based data collection, a KEEP button is displayed next to the COLLECT button.

TIP! *In event-based collection, time information is not recorded.*

Event Mode: Events with Entry

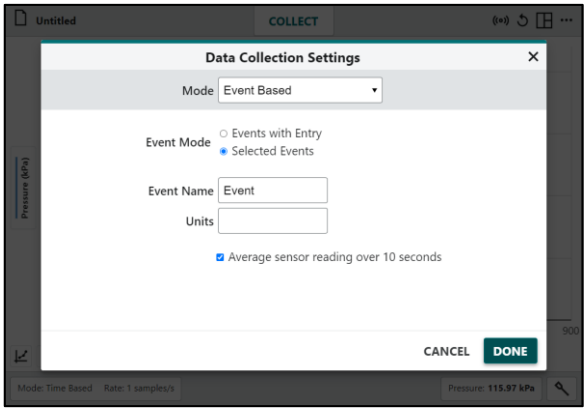
This event mode provides a prompt to enter the independent "Event" value each time you keep a data point.



TIP! *During event-based data collection, sensors are sampled 10 times each second while data collection is active.*

Event Mode: Selected Events

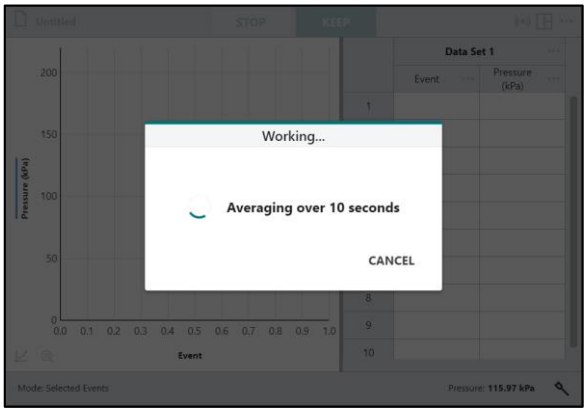
This event mode does not prompt for the "Event" value when you click or tap KEEP. Instead, the associated row number (1, 2, 3, ...) is automatically recorded as the "Event" value for each new data point.



Average over 10 seconds

This option reports the average sensor reading over a 10-second collection. Sensors are sampled at 10 samples per second.

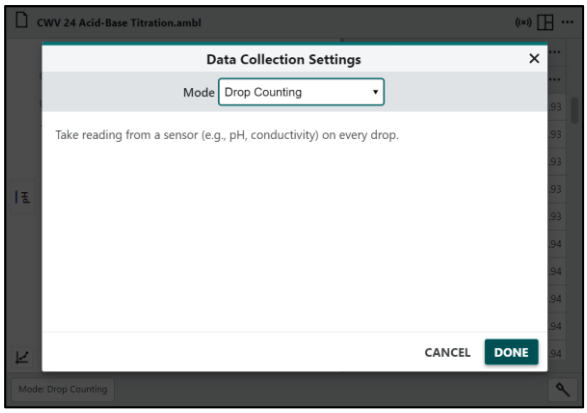
TIP! *Average over 10 seconds can be used with either Events with Entry or Selected Events event modes.*



Mode: Drop Counting

Drop Counting mode is the default mode whenever a Drop Counter is connected. When using this mode, data points are recorded every time a drop is detected by the Drop Counter.

TIP! *While you can manually set the mode to Drop Counting for any sensor configuration, data can only be collected when there is a Drop Counter and at least one other sensor.*

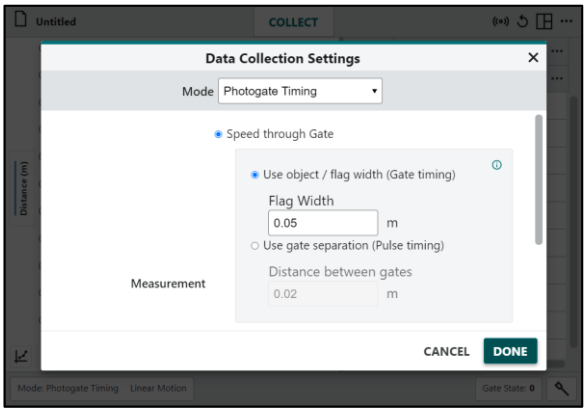


Mode: Photogate Timing

Photogate Timing mode is the default mode whenever a wired (BTD) Photogate, a Go Direct Photogate with only Gate State channels selected, or a Projectile Launcher is connected. When using this mode, the time a gate is blocked or unblocked is recorded as an object passes through the gate. The times are used to determine attributes of the motion of the object. Which attributes are calculated depend on the measurement type.

Speed Through Gate

This default option for two photogates reports the speed of an object as it passes between the gates.

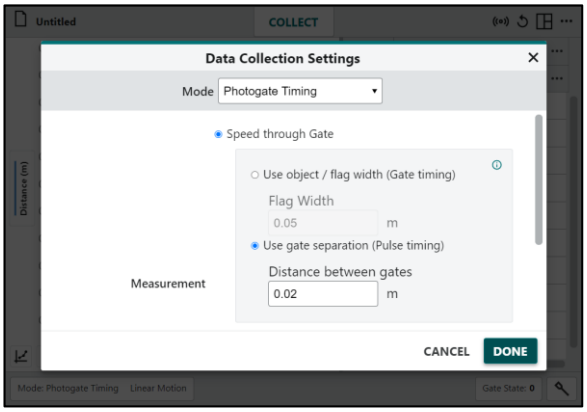


Use object / flag width

For a single photogate, the speed of an object passing through the gate is determined by dividing the width of the object that blocks the gate (the flag) by the time duration the object (flag) is blocking the gate.

Use gate separation

For two individual photogates or a double photogate, the speed of an object passing through the gate is determined by dividing the distance between the gates by the time duration between the blocked-events as the object passes the two gates.

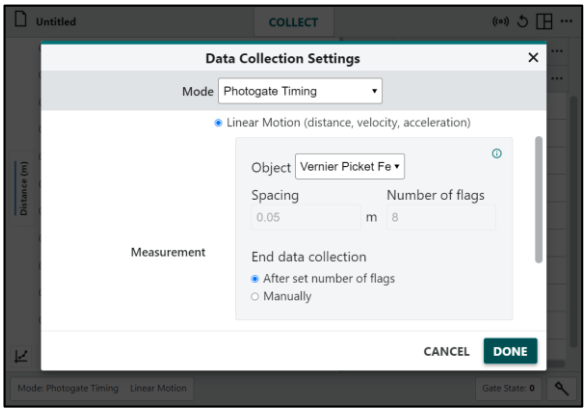


TIP! *You can find the average speed of an object as it passes between any pair of gates as long as the gate separation is known.*

Linear Motion (distance, velocity, acceleration)

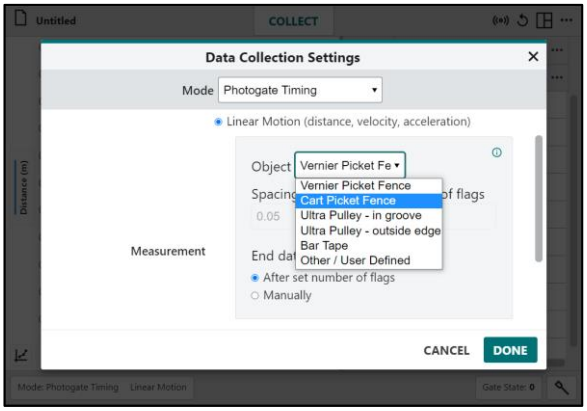
This is the default photogate option when only one photogate is used.

This option reports the linear position of an object at times associated with the blocked times of multiple, equal-spaced flags on an object. The first blocked event determines the zero position. The position *vs.* time data is used to calculate velocity and acceleration data.



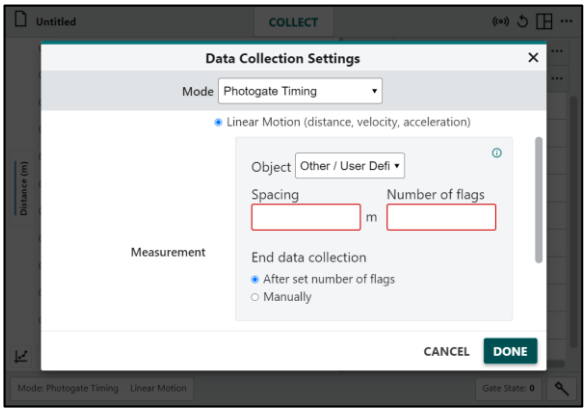
Object

Photogate accessories sold by Vernier can be selected from the Object dropdown list. These objects have a predefined spacing and number of flags that are shown when the object is selected.



For objects not made by Vernier, select Other / User Defined and manually enter the Spacing and Number of flags.

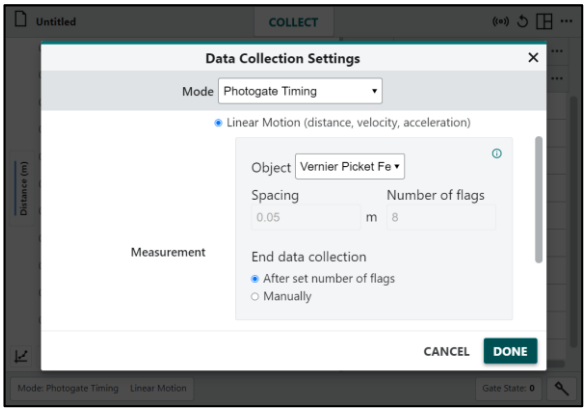
TIP! *If the object is a wheel with multiple spokes, Spacing is the circumference of the wheel divided by the number of spokes, and Number of flags equals the number of spokes.*



End Data Collection

Select After Set Number of Flags to automatically stop collection after the object has completely passed through all gates.

Select Manually to continuously collect data until you click or tap STOP.



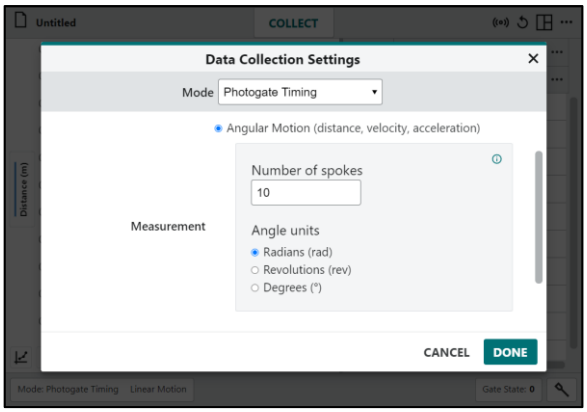
Angular Motion (distance, velocity, acceleration)

This option reports the angular position of an object at times associated with the blocked times of multiple, equal-spaced spokes on a wheel. The first blocked event determines the zero position. The angular position *vs.* time data is used to calculate angular velocity and angular acceleration data.

Angle Units

Select the desired angle unit for your experiment. The default unit is radians.

TIP! *2π radians = 1 revolution = 360°*



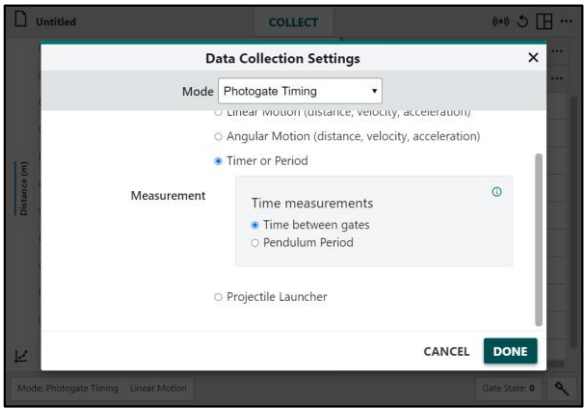
Timer or Period

This option includes two different time measurements: Time between gates and Pendulum period.

Time between gates

The time between blocked events from two gates is reported as Pulse Time. Measurements are displayed only when Gate 2 is blocked after Gate 1.

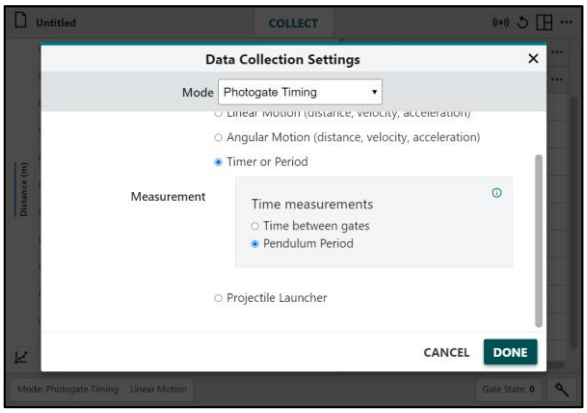
TIP! *You can also use this option to measure times between successive blocks of a single photogate.*



Pendulum Period

The time between every second blocked event for a single gate is reported as Period.

TIP! *The pendulum bob must completely pass through the gate twice for a period measurement to be recorded.*

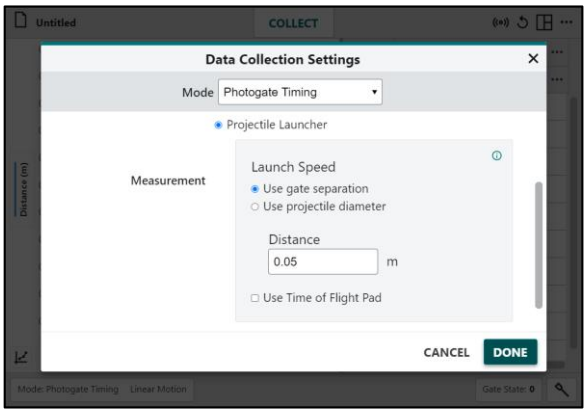


Projectile Launcher

This option is the default option when using a Projectile Launcher. The photogates built into the projectile launcher are used to determine the launch speed of the projectile.

Use Gate Separation

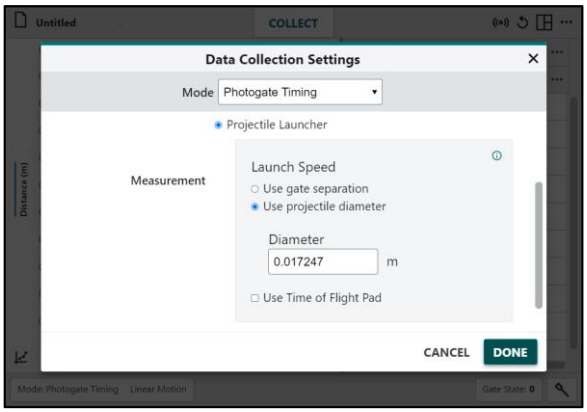
This option uses the distance between the two launch photogates to determine the launch speed of the projectile. The default distance is 0.05 m.



Use Projectile Diameter

This option uses the diameter of the projectile to determine the launch speed as the projectile passes through the first launch gate. The default diameter is 0.017247 m or 11/16 inches.

TIP! *You can use two wired [BTD] photogates with this mode as long as the photogates are daisy-chained together, reporting a single gate-state column in the data table.*

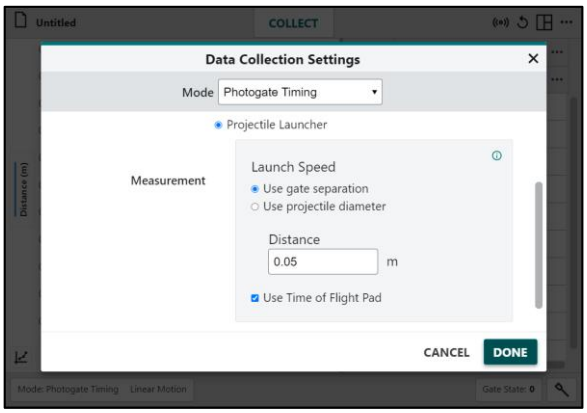


Use Time of Flight Pad

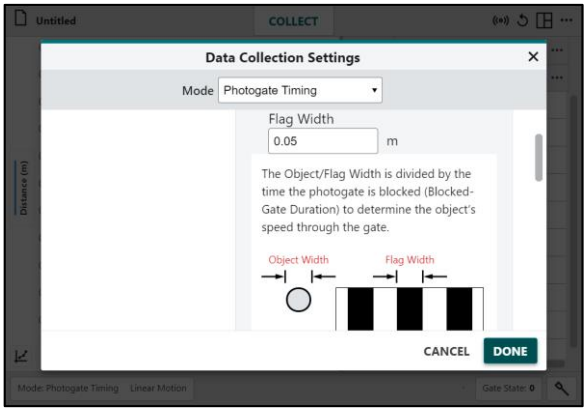
The Time of Flight Pad accessory is required when using this option.

This option reports Time of Flight as the time between blocking the first launch gate and striking the Time of Flight Pad.

TIP! *You can use the Time of Flight Pad with either Launch Speed configuration.*



TIP! *You can click or tap Info, , to access Photogate setup information for any photogate timing measurement.*

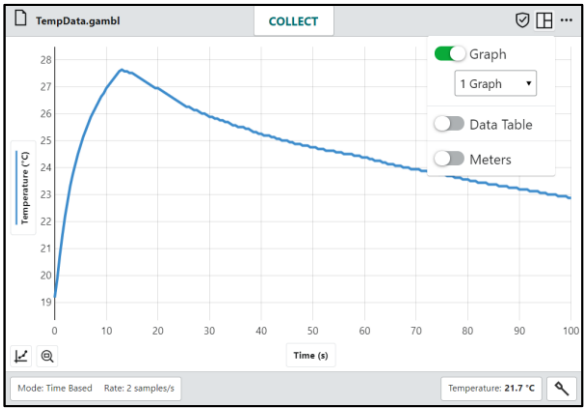


IV. Setting Up the Display (Graph, Data Table, and Meters)

Graphical Analysis automatically displays a view based on the experiment type, data-collection mode, and connected sensors. You can use this recommended view or modify the view using the options provided.

Click or tap View Options, , then modify the options as desired.

TIP! *When the Graphical Analysis Pro features are unlocked, you can also display a video. See Adding a Video to a Graphical Analysis Pro Data File in Chapter 8.*



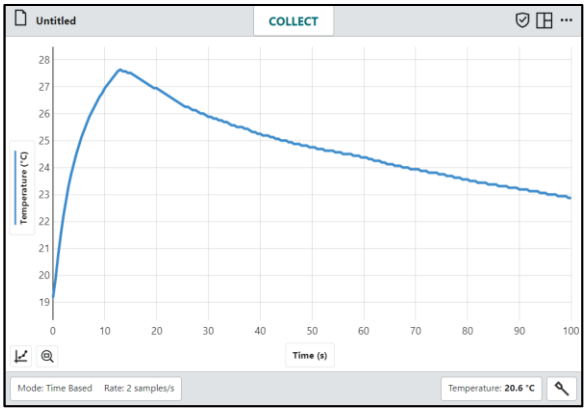
Using Only a Single Display Element

For a full-screen view of a Graph, Data Table, or Meter use only one of the options. The graph element can show one, two, or three graphs.

1 Graph

This is the default view of time-based data collection with a single sensor.

This view is also used when there are multiple sensors all using the same unit of measure.



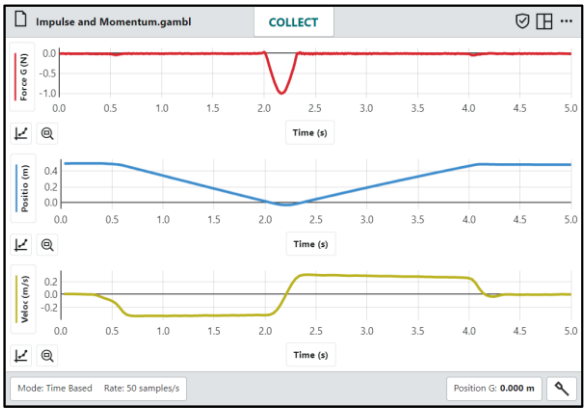
2 Graphs

This is the default view of time-based data collection with two (or more) sensors when the sensors have two different units of measure.

This is also the default view when using some motion detectors where the first graph plots position *vs.* time and the second graph plots velocity *vs.* time.

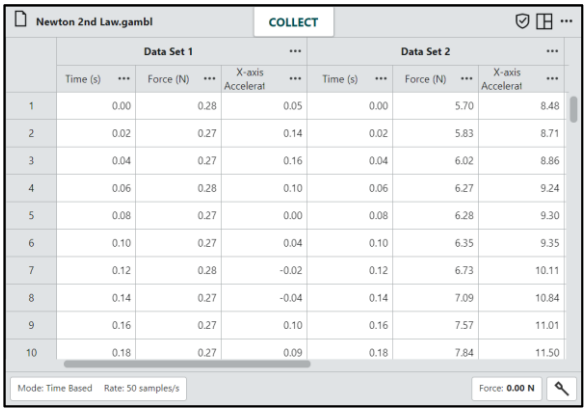
3 Graphs

This is the default view of time-based data collection with three or more sensors when the sensors have three different units of measure.



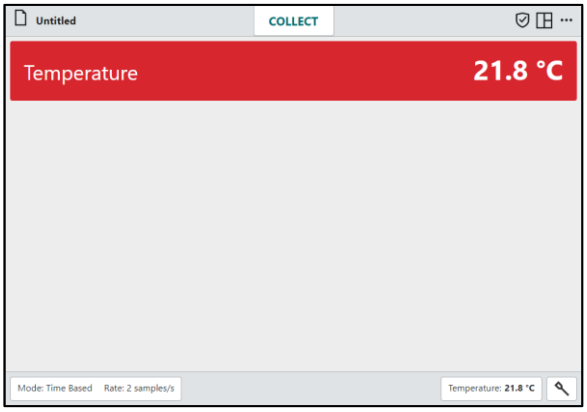
Table

This view shows the data table. This view is not displayed by default.



Meter

This view shows large sensor meters for the connected sensors. This view is not displayed by default.



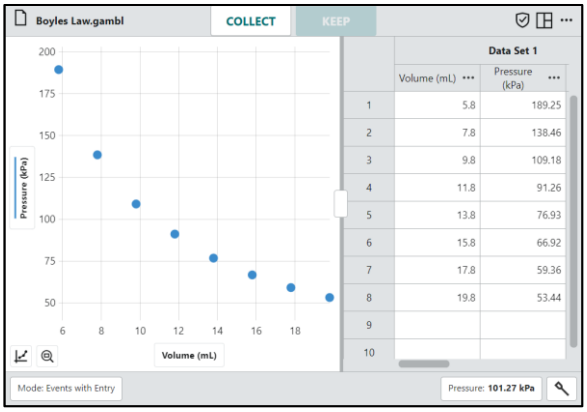
Using Two Display Elements

You can choose to show two elements such as a graph and data table. The display is split vertically to show the two elements side-by-side. The split can be adjusted by dragging the resize handle,  , located on the separating line.

Graph and Data Table

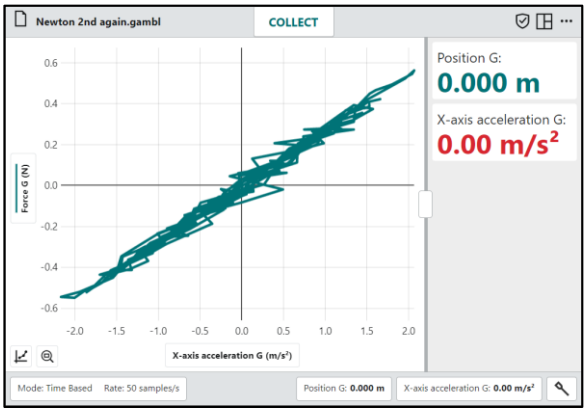
This is the default view for event-based, drop counting, photogate timing, and manual entry experiments.

The data table is always displayed to the right of the graph. The graph region can display one, two, or three graphs as needed.



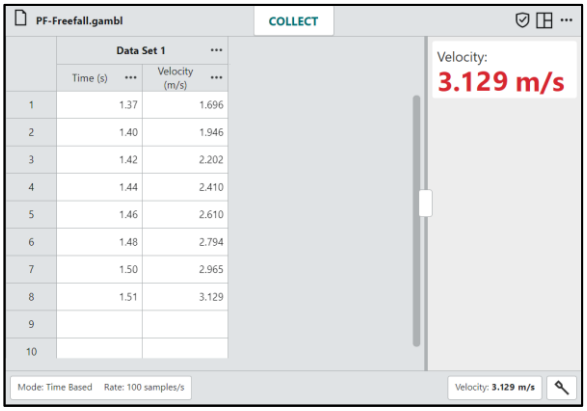
Graph and Meter

Sensor meters are displayed to the right of the graph. The graph region can display one, two, or three graphs as needed. This view is not displayed by default.



Data Table and Meter

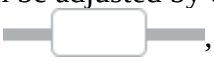
Sensor meters are displayed to the right of the data table. This view is not displayed by default.

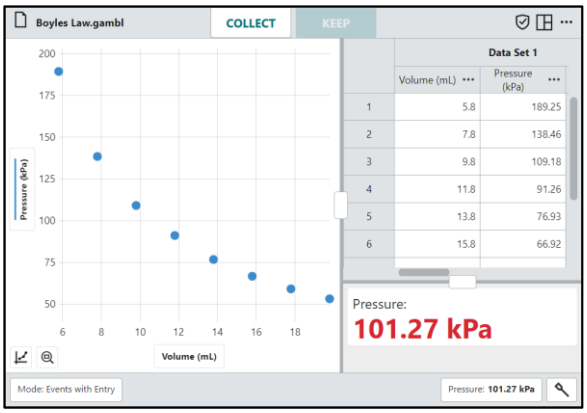


Using All Three Display Elements

Graph, Data Table, and Meter

When using all three elements, the graph is shown on the left and can display one, two, or three graphs.

The right region is split horizontally to show the data table above the sensor meter(s). The various splits can be adjusted by dragging the resize handles,  , located on the separating lines.

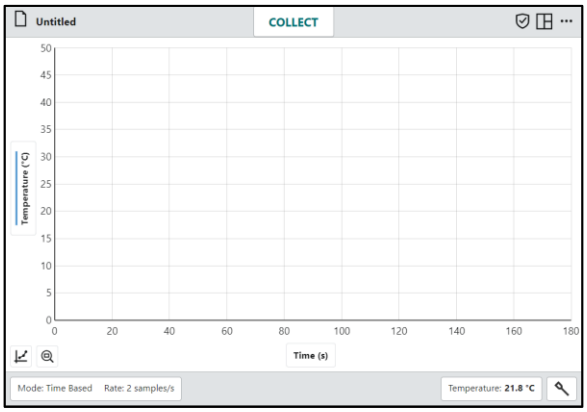


V. Collecting Data

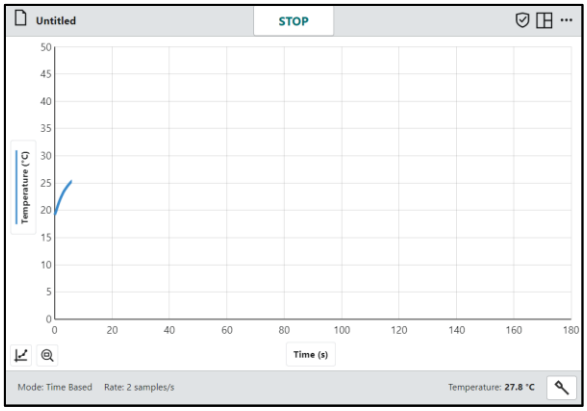
Time-Based Data Collection

Click or tap COLLECT to start data collection.

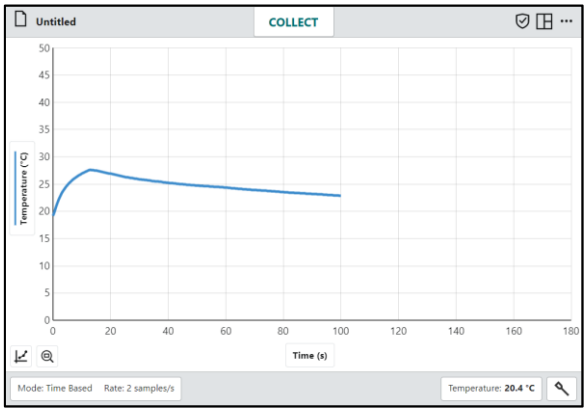
TIP! *You can use the space bar on a computer or Chromebook keyboard to start and stop data collection while Graphical Analysis has focus.*



While collecting data, some toolbar buttons, such as the mode button and sensor meters, are no longer accessible.



Click or tap STOP to stop data collection, or wait until data collection ends automatically.



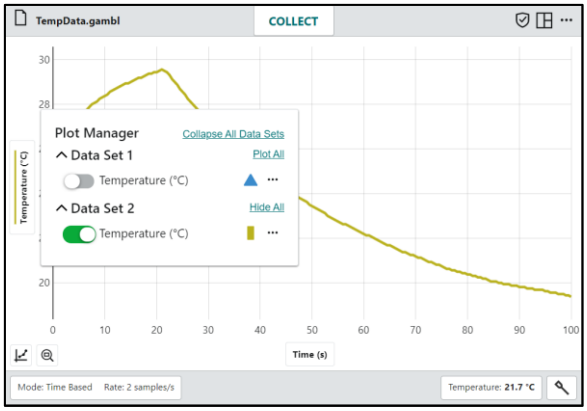
Click or tap Zoom, , to scale the graph to fit all data points.

The left and right boundaries match the left and right extremes of your data. The top and bottom boundaries automatically adjust to show all data.

Collecting Multiple Data Sets

To collect another data set, click or tap COLLECT again. Your original data set is saved, and the new data set is displayed on the graph.

TIP! *To plot your original data set, click or tap the y-axis label,* Temperature (°C)*, and turn on columns from the desired data set.*



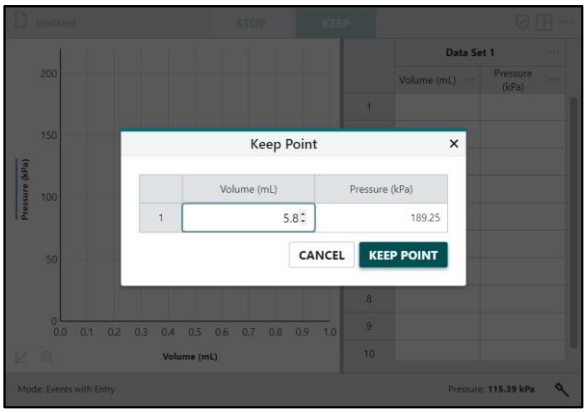
Event Based Data Collection

Click or tap COLLECT to start data collection. This enables the KEEP button.

Click or tap KEEP when you are ready to record a data point.

When Events with Entry is selected, you are prompted for the "Event" value.

TIP! *The sensor reading at the time you select* KEEP *is shown in the Keep Point box. Changes to the sensor value while the box is shown are ignored until the box is dismissed.*



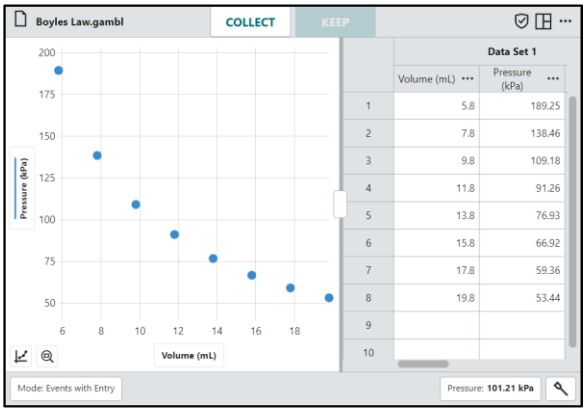
Enter the corresponding "Event" value for this data point, then click or tap **KEEP POINT** to record the entry in the data table.

The point is automatically plotted on the graph.

Continue as needed until you have collected all of your data points.

TIP! *The graph scales automatically as you* **KEEP** *each point to ensure all data points are shown on the graph.*

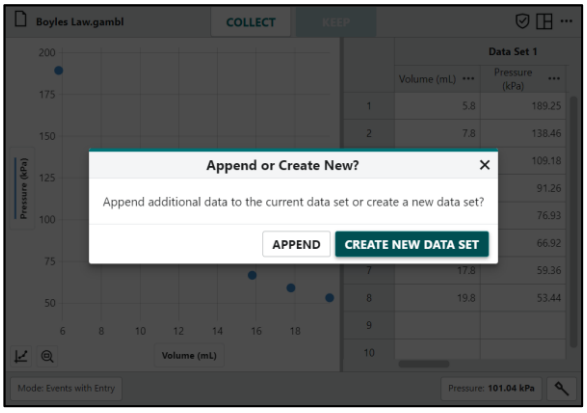
Click or tap **STOP** to stop data collection and continue with data analysis.



Collect Multiple Data Sets

To collect another data set, click or tap **COLLECT** again. For event-based data collection, you can append new data to your existing data set or start a new data set.

TIP! *To plot your original data set, click or tap the y-axis label,* **Pressure (kPa)**, *and turn on columns from the desired data set.*



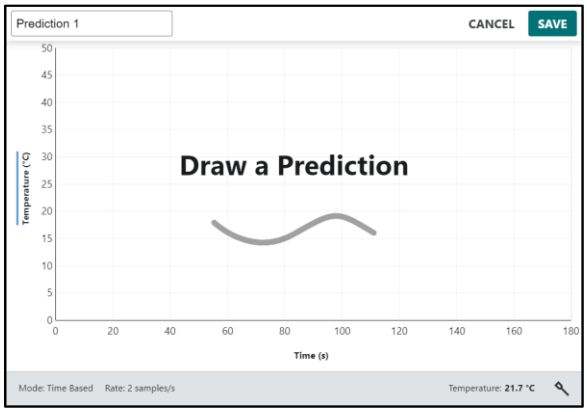
VI. Adding a Prediction

The Add Prediction tool is a free-hand sketching tool for adding predictions to a graph.

TIP! *Requiring students to draw predictions prior to data collection has been shown to increase student understanding of science concepts.*

Click or tap Graph Tools, , and choose Add Prediction to access the tool.

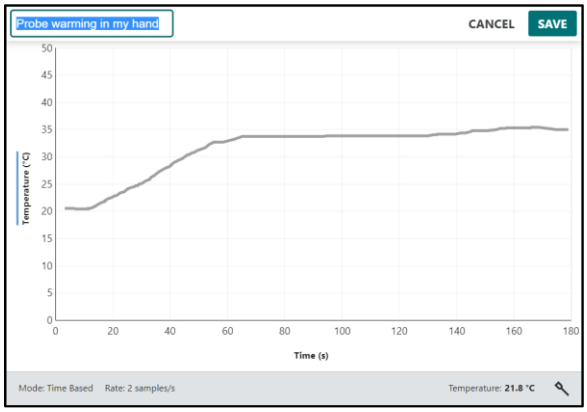
If you are viewing multiple graphs or a graph with another display element such as a meter or data table, the graph to which you are adding the prediction expands to full screen while the Add Prediction tool is active.



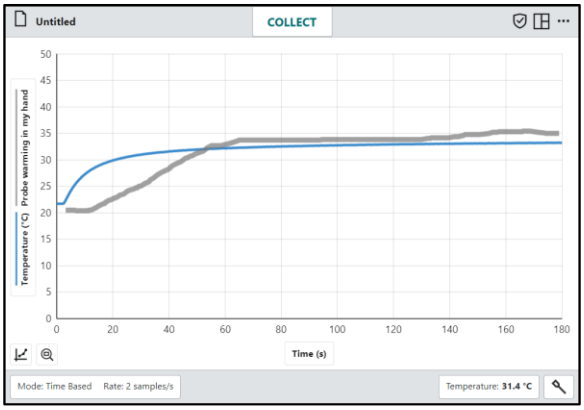
Click-and-drag or touch-and-drag across the graph to sketch your prediction.

Name the prediction if desired, then click or tap SAVE to add the prediction to your graph.

TIP! *If you do not like your first prediction attempt, drag across the graph again to remove the first, and draw a new prediction.*



Collect data to compare your predication with real data.



To hide a prediction from the graph, click or tap the y-axis label and turn off the prediction.

To delete a prediction, click or tap the y-axis label, then click or tap Other Options, •••, next to the prediction, and choose Delete Prediction.

VII. Graph Matching with Motion Sensors

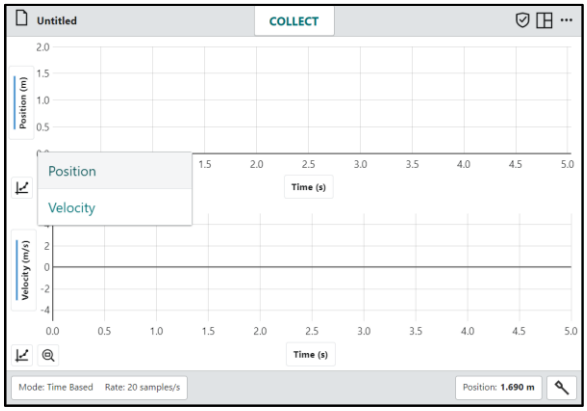
Click or tap Graph Tools, , and choose Add Graph Match to have a position or velocity target drawn on the graph.

Add Graph Match is only available when a Motion Detector, Motion Encoder, or Sensor Cart is connected.

TIP! *When more than one graph is displayed, you can choose Add Graph Match from any graph to get started.*

Choose a Position or Velocity target to match.

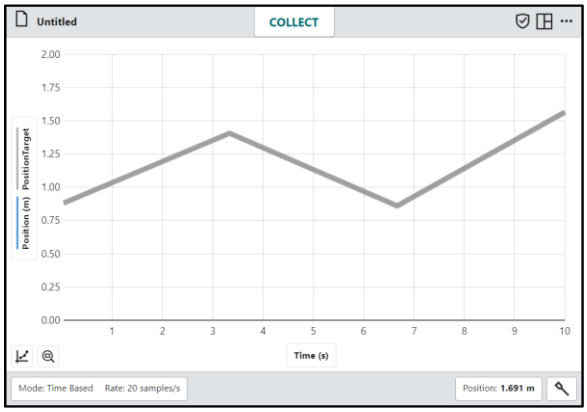
TIP! *When working with students that have never done a graph match, start with a position match.*



Position Match

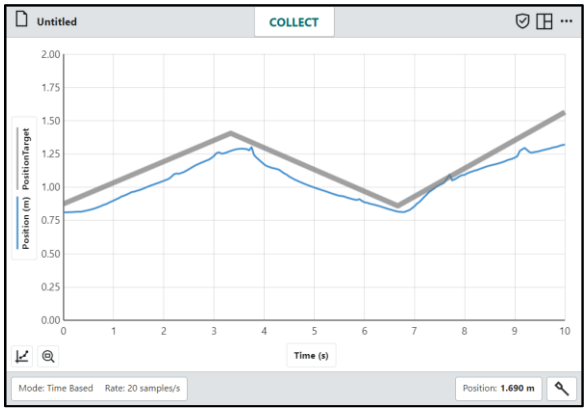
A Position Match contains three linear segments.

TIP! *The Position Target is always displayed in a single graph view regardless of the display settings when Graph Match is selected.*



Start data collection and move so your detected motion matches the displayed graph.

TIP! *You can repeat data collection as often as desired. To get a different match, select Graph Match ▸ Position again.*



Velocity Match

A Velocity match contains three horizontal (constant velocity) segments.

To get a different match, select Graph Match ▸ Velocity again.

TIP! *The Velocity Target always displays in a single graph view regardless of the display settings when Graph Match is selected.*

To hide a Position or Velocity Target from the graph, click or tap the y-axis label and turn off the Graph Match target.

To delete a Graph Match target, click or tap the y-axis label, then click or tap Other Options, ⋯, next to the target, and choose Delete Graph Match.

VIII. Analyzing Your Data

See Chapter 6–Analyzing Your Data

CHAPTER 3—CONNECTING TO A DATA SHARING SOURCE

Graphical Analysis can receive wirelessly streamed sensor data from a Data Sharing source such as LabQuest 2, LabQuest 3, or a computer running our Logger *Pro* 3 software.

When the Graphical Analysis Pro features are unlocked, you can also connect to a Graphical Analysis Pro Data Sharing Source.

I. Data Sharing with a LabQuest or Logger *Pro* Data Sharing Source

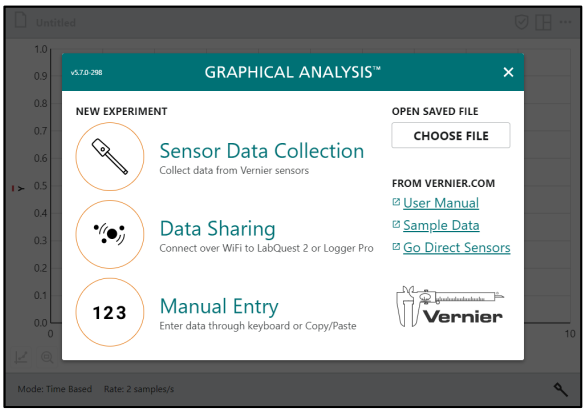
How LabQuest or Logger *Pro* Data Sharing Works

- Set up an experiment with Vernier sensors and LabQuest 2, LabQuest 3, or Logger *Pro* 3 software configured to be a data sharing source. For more information, see https://www.vernier.com/til/2675
- Use Graphical Analysis to wirelessly connect to the Data Sharing Source using Wi-Fi. Both devices must be on the same Wi-Fi network; however, the Wi-Fi network does not require internet connectivity.
- Data collected on the host device are shared with the connected devices. The data can be streamed live during data collection or transferred in full after data collection is complete.
- Each recipient of the data can perform an individual analysis of the shared data on their device. Data analysis done on the host or any connected device is not shared with the other devices.

Connecting to a LabQuest or Logger *Pro* Data Sharing Source

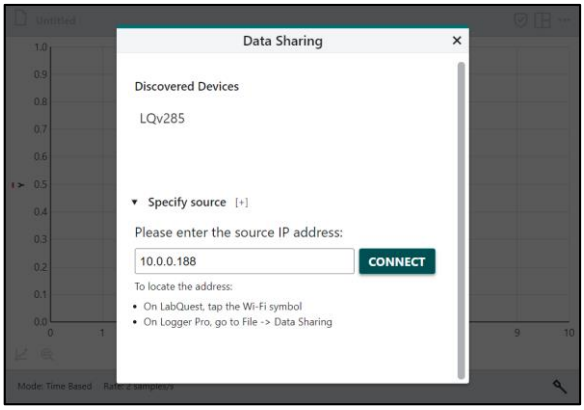
1. Connect your computer, Chromebook, or mobile device to the same Wi-Fi network used by the Data Sharing source (LabQuest 2, LabQuest 3, or a computer running Logger *Pro* 3).

2. Launch Graphical Analysis.

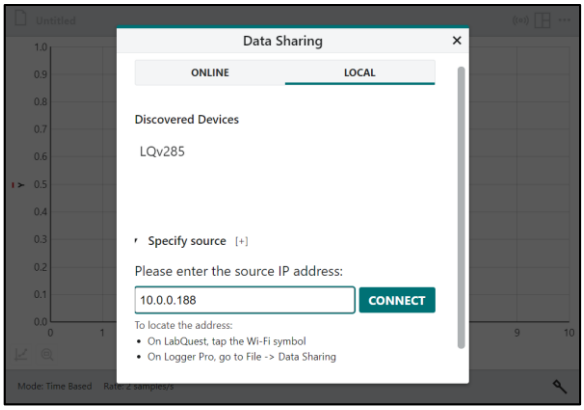


3. Click or tap Data Sharing. Discovered Devices are listed automatically.

   TIP! *If your device is not listed, you can connect to it by choosing Specify Source and manually entering the data sharing source's IP address.*

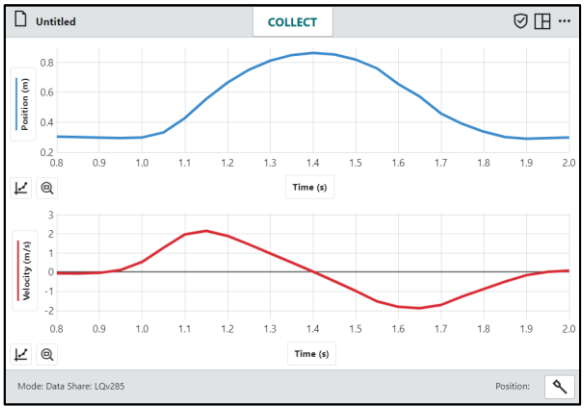


   If you are using Graphical Analysis Pro, you must select the Local option to connect to a LabQuest or Logger *Pro* Data Sharing source.



4. Click or tap the name of the Data Sharing source (or enter the data sharing source IP address, then click or tap CONNECT) to connect to the source.

   TIP! *Bottom toolbar buttons are not active during a Data Sharing activity. Data collection and sensor settings are modified on the Data Sharing source.*



II. Data Sharing with a Graphical Analysis Pro Data Sharing Source

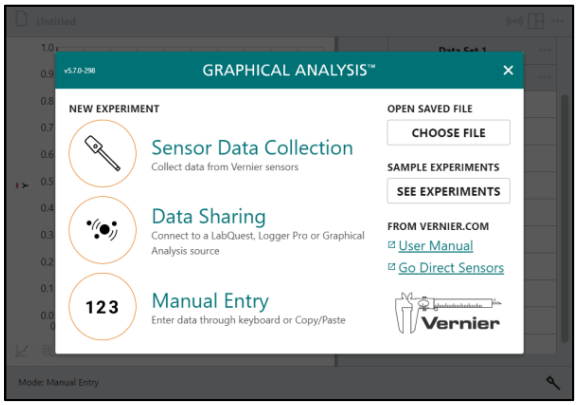
How Graphical Analysis Pro Data Sharing Works

- Set up a sensor data-collection experiment using Vernier sensors and Graphical Analysis with the Graphical Analysis Pro features unlocked.
- Configure Graphical Analysis Pro on the host device to Data Share and share the data sharing ID with everyone that needs it. For more information, see Setting up Graphical Analysis Pro as the Data Sharing Host
- Participants use the data sharing ID to join the session on their devices that also have the Graphical Analysis Pro features unlocked. All devices need a live internet connection to make this possible.
- Data collected on the host device are shared with the connected devices. The data can be streamed live during data collection or transferred in full after data collection is complete.
- Each recipient of the data can perform an individual analysis of the shared data on their device. Data analysis done on the host or any connected device is not shared with the other devices.

Connecting to a Graphical Analysis Pro Data Sharing Source

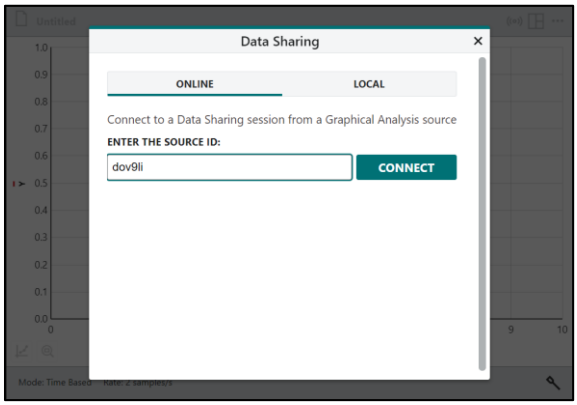
1. Make sure your device has a live internet connection, then launch Graphical Analysis.

   TIP! *You must unlock the Graphical Analysis Pro features on your device in order to connect to a device hosting a Graphical Analysis Pro data sharing session.*



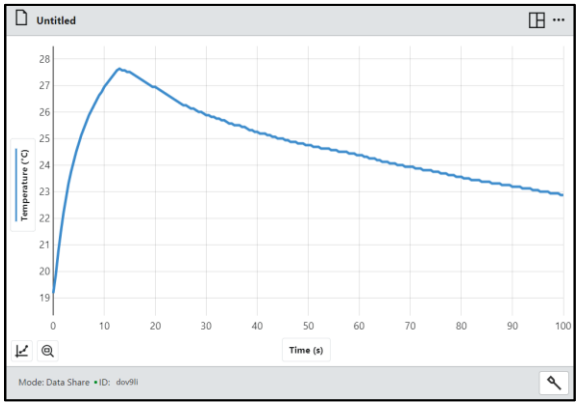
2. Click or tap  Data Sharing to connect to a Data Sharing source. Enter the six-digit Data Sharing ID code provided to you by the Data Sharing host.

   TIP! *The Online option is only used with Graphical Analysis Pro data sharing sources. Use the Local option when connecting to a LabQuest 2, LabQuest 3, or Logger* Pro *3 data sharing source.*



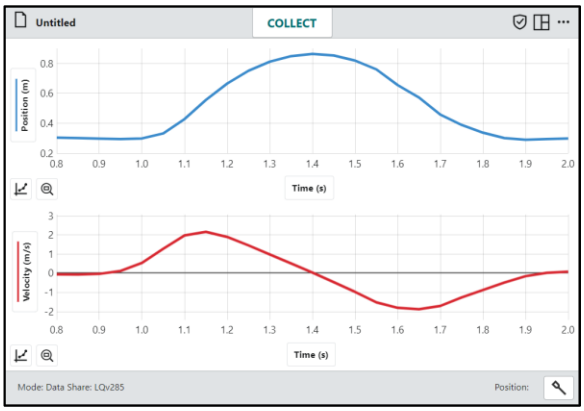
3. Click or tap **CONNECT** to connect to the data sharing source. You can verify that you are connected to the correct source by checking the source ID displayed in the lower left corner of the screen.

   TIP! *If the data sharing host's file includes a video or contains data analysis such as a curve fit, your file will not include those items. Only the host's data is shared with the connected devices.*



III. Using Graphical Analysis as a Data Sharing Client

When you are connected to a data sharing host, the host device sends graph configuration information and any collected data. As the host collects additional data, those data are also plotted on the connected devices as long as you have not interacted with the graph setup in any way.



Any data analysis done on the host device is not transferred to your device as the intention is that you perform your own data analysis.

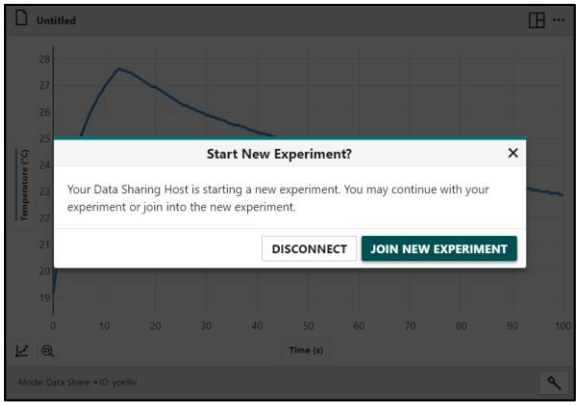
Changing the displayed view, rescaling the graph, examining a data point, or starting any data analysis can cause your instance of the shared data to stop automatic graph updates. Your device continues to get the additional data, they just no longer automatically display on your graph.

To return to updating automatically as the host device updates, click or tap the File menu, **Untitled**, and choose New Experiment. Follow the steps for connection to the host device again.

If the host starts a new data-collection experiment or opens a new file while data sharing, you are prompted to join the new experiment.

Click or tap **JOIN NEW EXPERIMENT** to remain connected to the data sharing host.

TIP! *If you need to save your work from the previous experiment before continuing to the next experiment, click or tap Disconnect, save the file, then reconnect as you did before.*

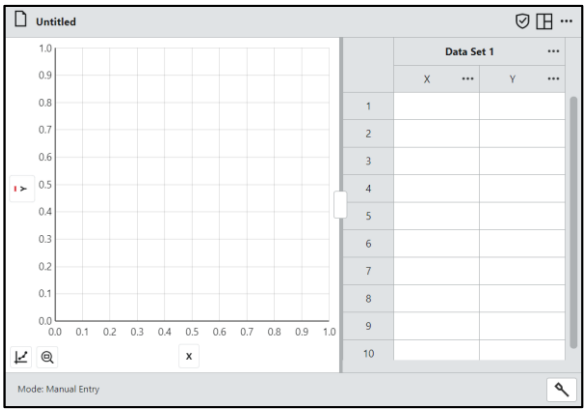


IV. Analyzing Your Data

See Chapter 6–Analyzing Your Data

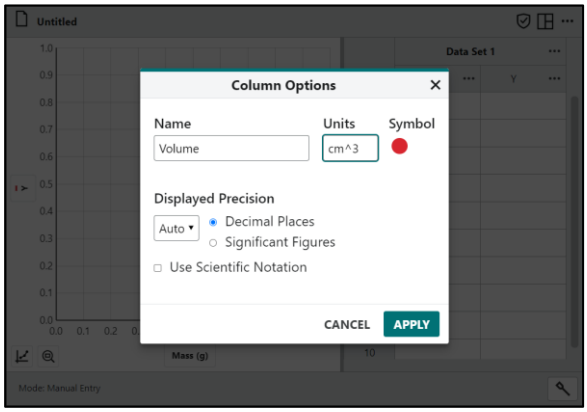
CHAPTER 4—MANUALLY ENTERING DATA

Click or tap 123 Manual Entry to initiate an experiment where you manually enter data into a data table. You can use Graphical Analysis to analyze data you collect without sensors as well as data found in textbooks or on the internet.



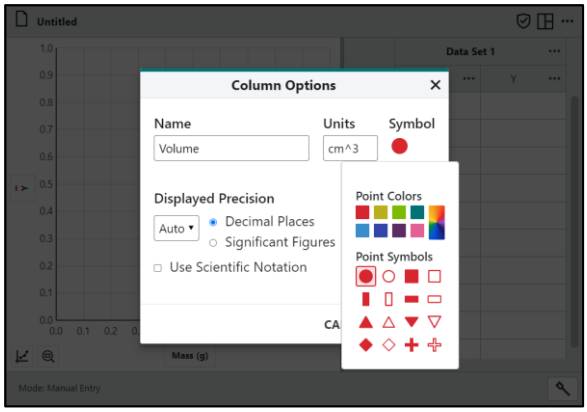
I. Setting up Columns

Click or tap Column Options, •••, next to a column name in the data table, or you can access Column Options from the y-axis Plot Manager. Choose Column Options to name the column, define the units, and select the displayed precision.

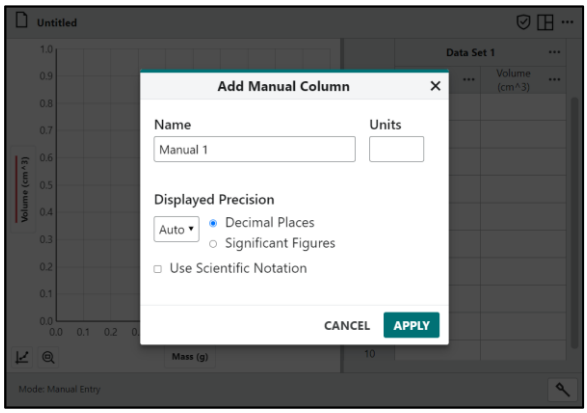


Click or tap the Symbol icon (e.g.,), to modify the Point Colors and Point Symbols used when the column is plotted on a graph.

Click or tap **APPLY** to save the changes.



Adding Additional Manual Columns

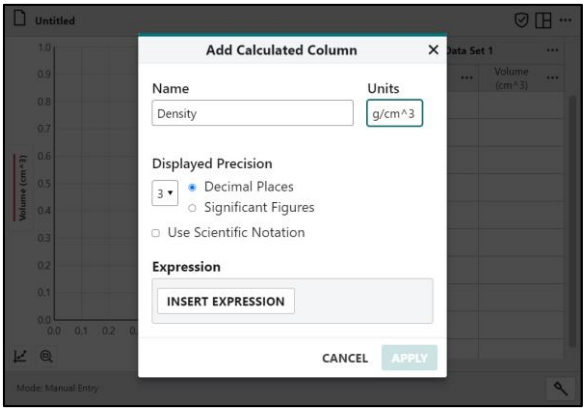


Click or tap Column Options, •••, next to a column name, and choose Add Manual Column to create a new manual entry column. The new column is added to the right of the column used to access the column tools.

You can modify the column name, add units, and adjust the display precision of the new column as desired.

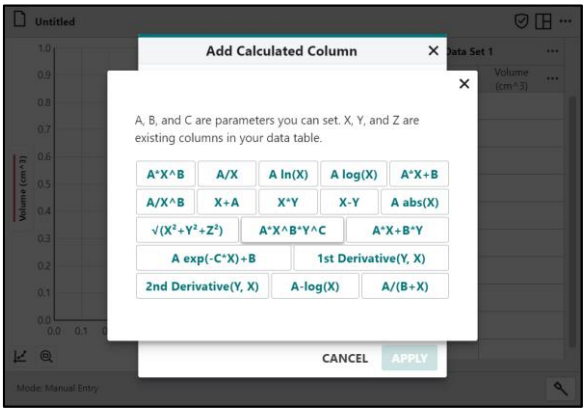
Click or tap **APPLY** to save the changes.

Adding a Calculated Column



Click or tap Column Options, •••, next to a column name, and choose Add Calculated Column to create a new column with values that are based on other columns through a mathematical formula.

You can modify the column name, add units, and adjust the display precision of the new column as desired.

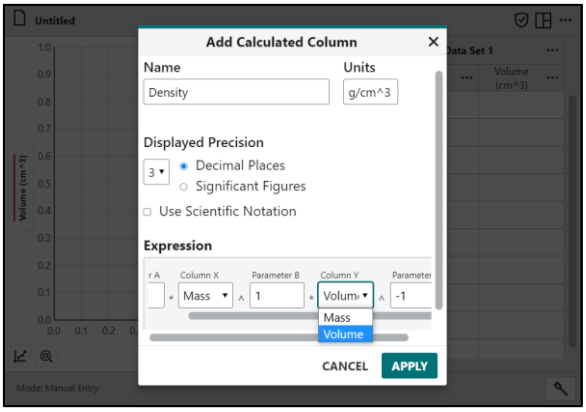


Click or tap **INSERT EXPRESSION** to view your expression options. Select the desired expression to use for your calculated column.

NOTE: A, B, and C represent constants. X, Y, and Z represent data columns from your data table.

TIP! *When the Graphical Analysis Pro features are unlocked, you can use user-defined expressions in your calculated columns. See Custom-Expression Calculated Columns in Chapter 8.*

The column from which you accessed the column tools is used in the calculated column expression by default. Adjust the columns and parameters as desired.

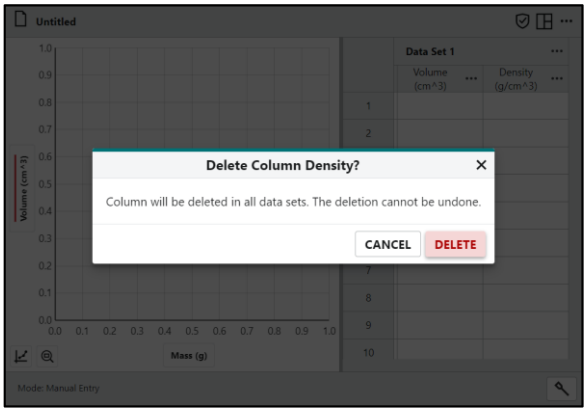


Click or tap **APPLY** to save the changes. The new calculated column appears to the right of the column used to access the Column Options.

TIP! *To edit a calculated column once it has been created, click or tap Column Options,* ••• *, next to the column name in the data table or y-axis Plot Manager and select Column Options.*

Deleting a Column

Click or tap Column Options, •••, next to a column name in the data table or y-axis Plot Manager, and choose Delete Column to remove Manual or Calculated Columns.

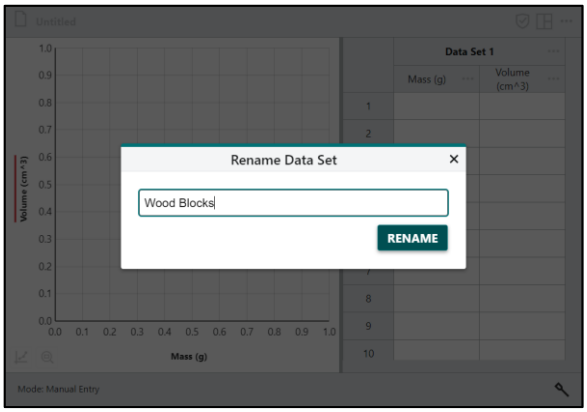


Click or tap **DELETE** to confirm the deletion. Deleting a column cannot be undone.

TIP! *The original X and Y data columns cannot be deleted.*

Renaming a Data Set

Click or tap Data Set Options, •••, next to a data set name in the data table, and choose Rename Data Set to change the default data set name.



Click or tap **RENAME** to save the changes.

Adding Additional Data Sets

Click or tap Data Set Options, •••, next to a data set name, and choose Add New Data Set to add an additional data set.

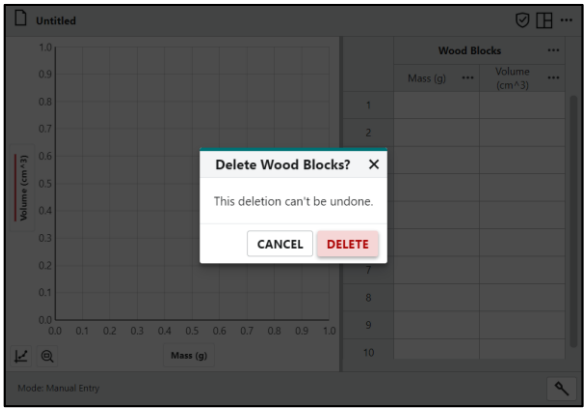
The new data set has the same columns and configurations as the original data set and is added to the data table after the last data set.

TIP! *The option to add additional data sets is only available for a Manual Entry experiment.*

Deleting a Data Set

Click or tap Data Set Options, •••, next to a data set name, and choose Delete Data Set to remove a data set.

Click or tap DELETE to confirm the deletion. Deleting a data set cannot be undone.



II. Entering Data in Your Data Table

Manual Data Entry

Double-click or double-tap a data table cell to add or edit the data.

Using the Cut, Copy, and Paste Tools

You can copy data between your data table and the system clipboard on your computing device.

Copy to the Clipboard

- **Windows**: Right-click and select Copy (or Ctrl-C)
- **macOS**: Command-C (⌘-C)
- **Chromebook**: Alt-click and select Copy (or Ctrl-C)
- **iOS, iPadOS,** and **Android** (and other touch-screen devices): Long-touch within the selection and select Copy

Cut (and Copy) to the Clipboard

- **Windows**: Right-click and select Cut (or Ctrl-X)
- **macOS**: Command-X (⌘-X)
- **Chromebook**: Alt-click and select Cut (or Ctrl-X)
- **iOS, iPadOS,** and **Android** (and other touch-screen devices): Long-touch within the selection and select Cut

Paste from the Clipboard

- **Windows**: Right-click and select Paste (or Ctrl-V)
- **macOS**: Command-V (⌘-V)
- **Chromebook**: Alt-click and select Paste (or Ctrl-V)
- **iOS, iPadOS,** and **Android** (and other touch screen devices): Long-touch the desired location and select Paste

TIP! *When using Paste to copy data from multiple columns, you must first add the appropriate number of manual columns to your data table.*

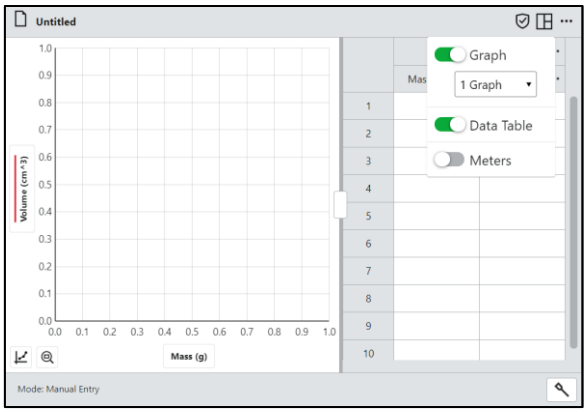
Selecting Cells in your Data Table

- To select a single cell, single-click or tap the cell.
- To select a range of cells, click-and-drag or touch-and-drag across the cells.
- To select a single row, click or tap a row number.
- To select a range of rows, click-and-drag or touch-and-drag across the row numbers.
- To select a single column, click or tap a column header.
- To select a range of columns, click-and-drag or touch-and-drag across the column headers.
- To select a single data set, click or tap a data set header.
- To select a range of data sets, click-and-drag or touch-and-drag across the data set headers.

III. Setting Up the Display (Graph, Data Table, and Meters)

Graphical Analysis automatically displays a graph and a data table in manual entry mode.

Click or tap View Options,  , then modify the options as desired. For more information, see Setting Up the Display (Graph, Data Table, and Meters) in Chapter 2.



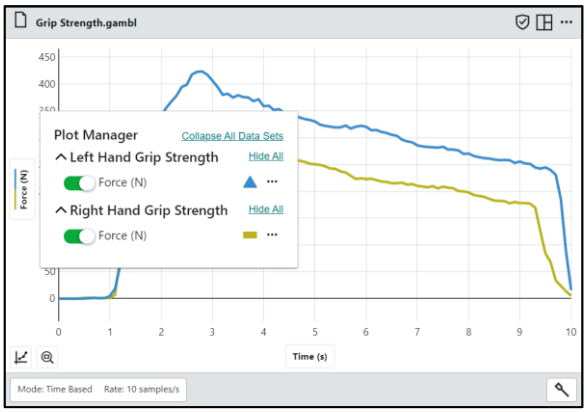
IV. Analyzing Your Data

See Chapter 6–Analyzing Your Data.

CHAPTER 5—CUSTOMIZING THE GRAPHS

I. Changing What is Plotted on the Graph

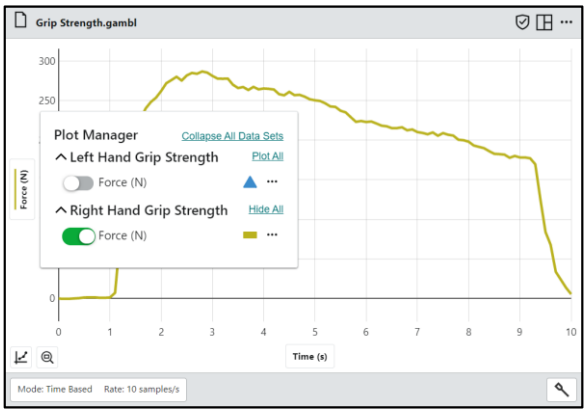
Click or tap the y-axis label, Force (N), to change the data that are plotted on the graph.



Click or tap a column name to add or remove the column data from the graph.

TIP! *Column data for all selected columns are shown on the graph.*

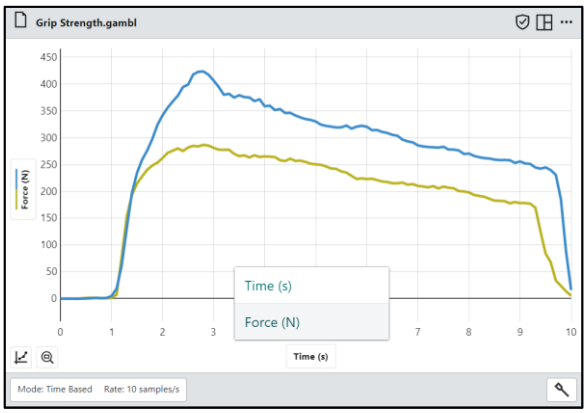
Click or tap a data set name to show or hide the selected column data for a specific data set.



TIP! *Use Expand All Data Sets and Collapse All Data Sets to quickly show or hide the columns from every data set.*

TIP! *Use the Plot All and Hide All options to quickly add or remove all data columns from the graph for a specific data set.*

Click or tap the x-axis label, Time (s), to select the desired independent variable for your graph. Only one column can be used as the independent variable for any graph.



TIP! *You cannot plot a column* vs. *itself. If the column you select for the independent variable is already plotted on the vertical axis (y-axis), that column is removed from the graph.*

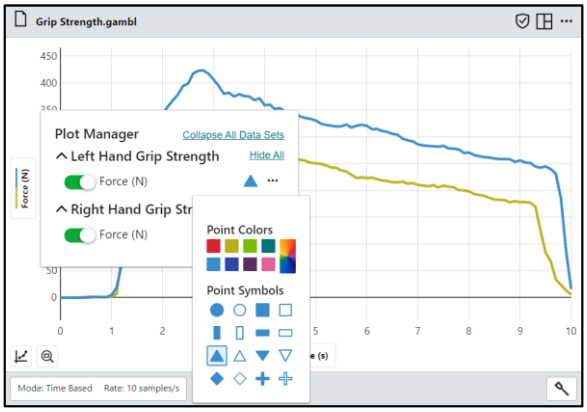
II. Adjusting the Graph Style

Changing the Point Symbol and Trace Color

Click or tap the y-axis label, Force (N), to access the Plot Manager.

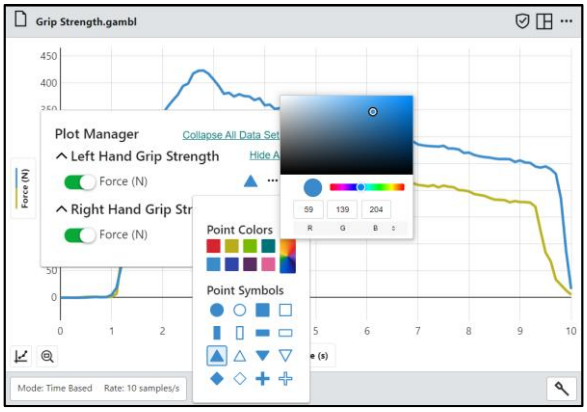
Click or tap Point Symbols, , and choose a different symbol or trace color.

TIP! *Changes to Point Colors and Point Symbols apply only to the column that was selected. The change is applied to any graph that is plotting that column's data.*



Click or tap for more color options.

TIP! *Custom colors can be defined using RGB, HSL, or Hex values. Click or tap the color values (e.g.,* R G B *) to change the input option.*

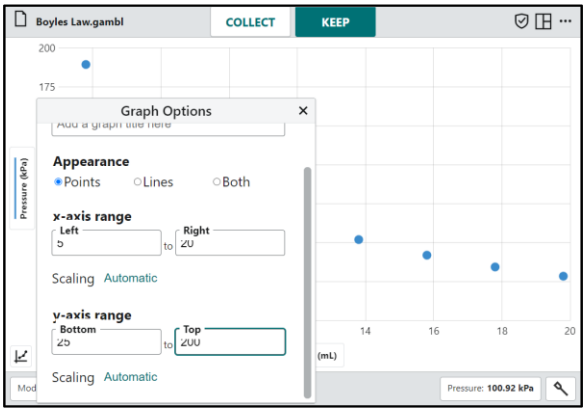


Modifying the Graph Appearance

Click or tap Graph Tools, , and choose Edit Graph Options to access the graph configuration tools.

Adjust the appearance as desired. Click or tap Close, , to dismiss Graph Options.

TIP! *When displaying multiple graphs, Graph Options changes only apply to the graph from which the tool is accessed. The changes are not applied to the other graphs.*

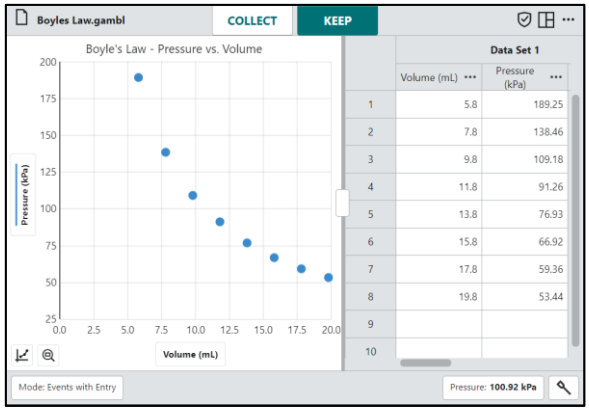


Points

Choose Points to show data as unconnected points.

This is the default option for manual experiments and sensor experiments that use event-based, drop counting, and photogate timing modes.

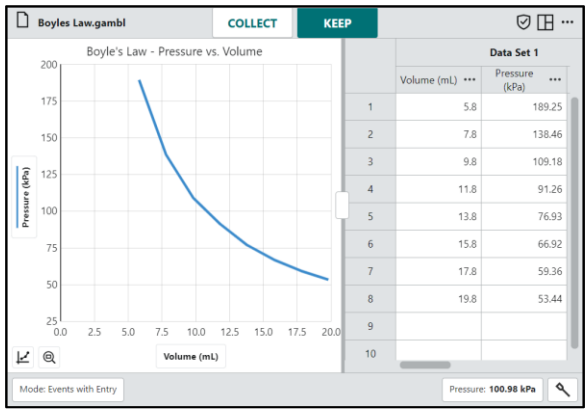
TIP! *Point symbols can be changed from the y-axis Plot Manager or Column Options.*



Lines

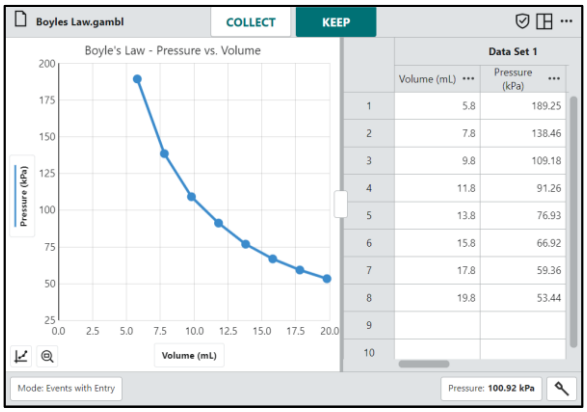
Choose Lines to show linear segments drawn between the data points. Individual point symbols are not shown.

This is the default option for time-based sensor experiments.



Both—Points and Lines

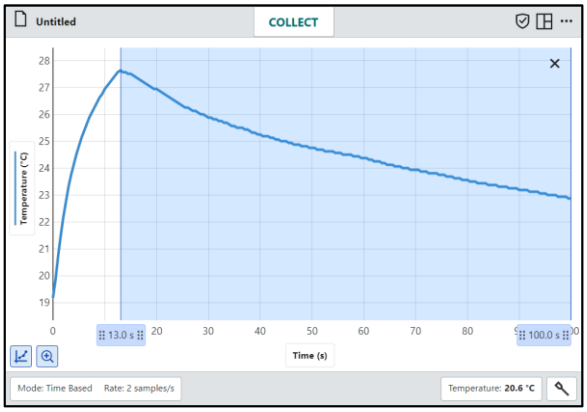
Choose Both to show data as dots connected by linear segments. This option is not displayed by default.



III. Scaling the Graph

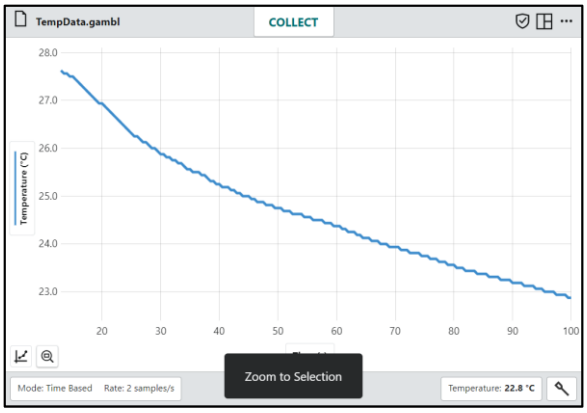
Zoom to a Selected Region

To scale the graph to a specific section of your data, click-and-drag or touch-and-drag across the graph to select the desired region.



TIP! *You can click-and-drag or touch-and-drag the boundaries of a selected region to adjust the region as needed.*

When a region is selected, click or tap Zoom to Selection,  , to scale the graph to fit the selection.



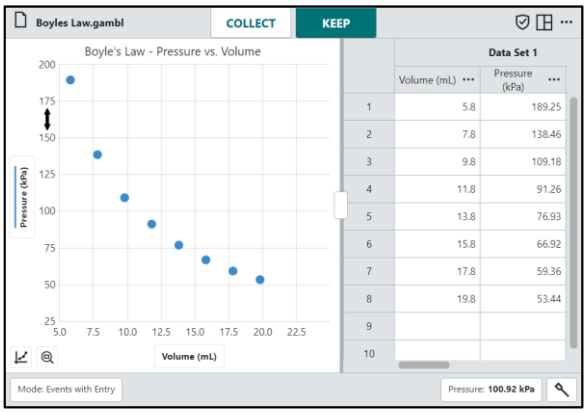
The left and right boundaries match the selected region. The top and bottom boundaries automatically adjust to show all data within the region.

You can click or tap Zoom to all Data,  , to rescale the graph to fit all data.

Panning the Graph

Click-and-drag or touch-and-drag near one of the axes to move (pan) the graph without changing the scaling. Starting near the horizontal axis (x-axis) pans the graph horizontally. Starting near the vertical axis (y-axis) pans the graph vertically.

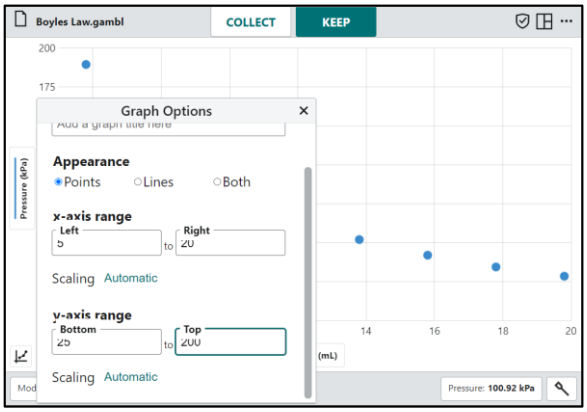
TIP! *Touch-screen devices can use a two-finger pinch gesture to pan and rescale the graph.*



Manual Scaling

Click or tap Graph Tools, , and choose Edit Graph Options to access the graph configuration tools.

Manually configure the x-axis and y-axis ranges to adjust the scaling as desired. Click or tap Close, , to dismiss Graph Options.



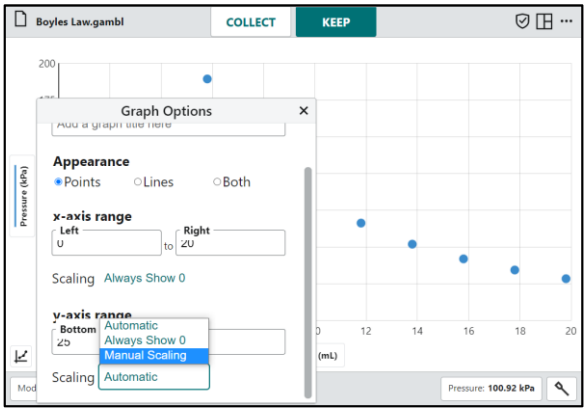
Scaling—Automatic

This default option allows the graph to scale larger during data collection to ensure all data points are visible.

TIP! *Manually entered values are not respected when the scaling option is set to Automatic.*

Scaling—Always Show 0

This option automatically scales the graph to include 0 for that axis. This setting does not change the automatic scaling of the graph larger, but it is respected when you manually rescale the graph using Zoom to all Data, .



Scaling—Manual

This option disables the automatic behavior related to scaling the graph larger during collection but is not respected when you manually rescale the graph using Zoom to all Data, .

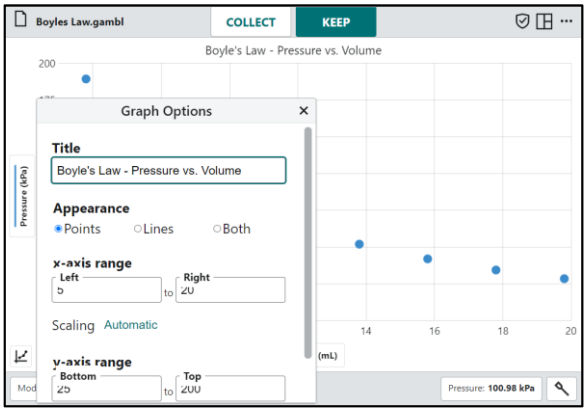
IV. Labeling the Graph

Adding a Graph Title

You can choose to add a title to your graph. Click or tap Graph Tools, , and choose Edit Graph Options.

Add or edit the Title as desired. Click or tap Close, , to dismiss Graph Options.

The title appears centered above the graph.

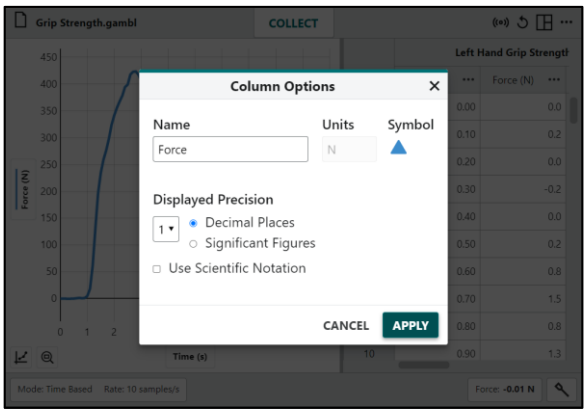


Modifying Axes Labels

The axis labels are populated from the column names. You can change the labels by changing the names of the columns.

Click or tap the y-axis label, Force (N), to access the Plot Manager. Click or tap Column Options, , next to the column you want to change and choose Column Options.

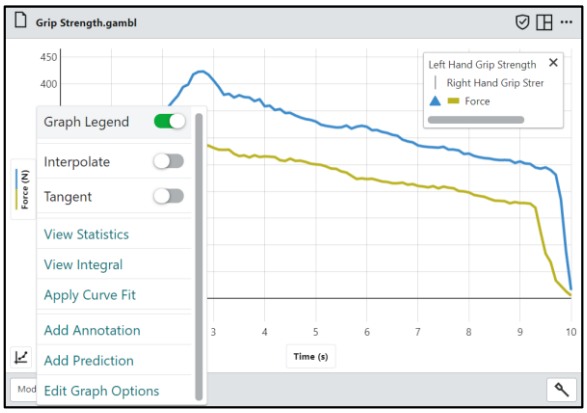
Change the column name as desired. Click or tap APPLY to save the changes.



To modify the x-axis label, Time (s), access Column Options for that column from the data table or temporarily plot the column on the y-axis.

Adding a Graph Legend

Click or tap Graph Tools, , and select Graph Legend. The legend shows the point symbol, color, and data for each plotted column.



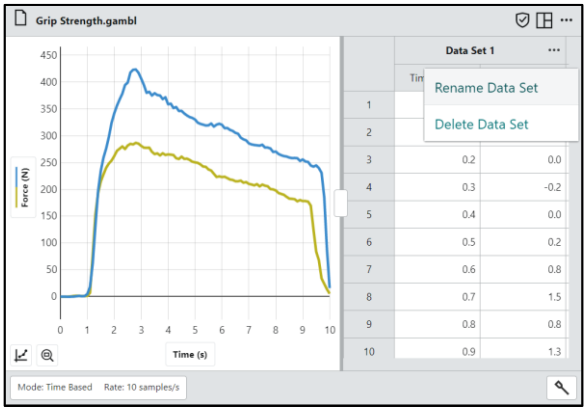
Click-and-drag or touch-and-drag the legend to reposition it on the graph. To dismiss the legend, click or tap Close, .

See Changing the Point Symbol and Trace Color for additional information.

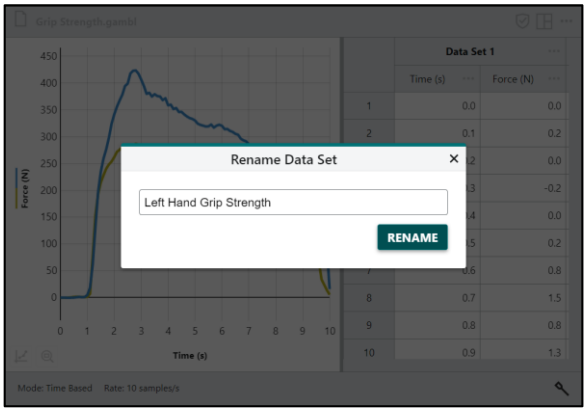
Rename Data Sets

While not shown directly on the graph, data set names are shown in the y-axis Plot Manager and in the Graph Legend.

From the data table, click or tap Data Set Options, , next to the data set for which you want to change the name.



Choose Rename Data Set to change the default data set name.

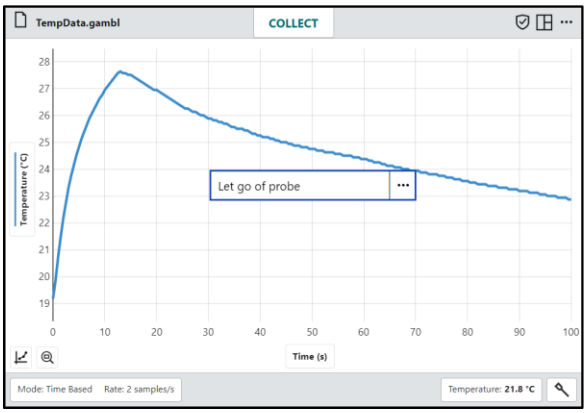


Click or tap **RENAME** to save the data set name.

Add Annotations

You can add text annotations to your graph to label key points or provide information about the data.

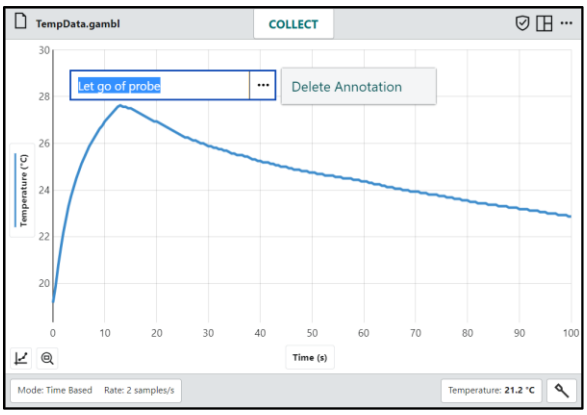
Click or tap Graph Tools, , and choose Add Annotation to add text labels to your graph. Edit the text as desired.



Click-and-drag or touch-and-drag an annotation to reposition it on the graph.

Double-click or double-tap an existing annotation to edit the text.

Click or tap Other Options, , to delete the annotation.

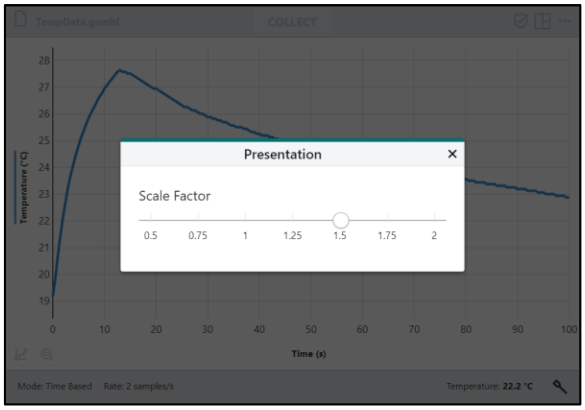


V. Modifying the Font-Size with Scale Factor

You can modify the font size used in the app. This is particularly useful when presenting the app with a projector or viewing the app on a device with a high-resolution screen.

Click or tap Other Options, ⋯, from the top tool bar and choose Presentation. Adjust the Scale Factor as desired.

TIP! *Reduce the Scale Factor when viewing multiple graphs to see more detail on each graph.*



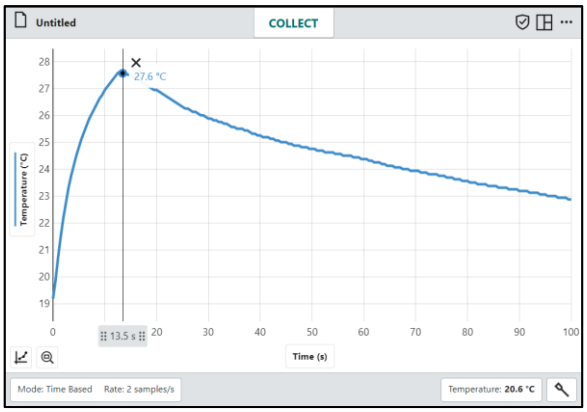
CHAPTER 6—ANALYZING YOUR DATA

I. Examining Data Points

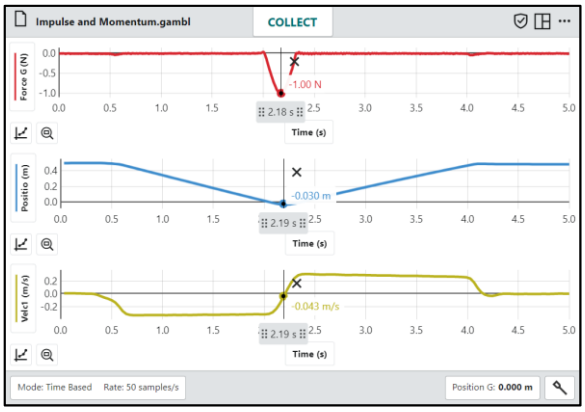
Click or tap the graph to examine a point of interest. The coordinates of the point are shown.

Click or tap a different point or drag the Examine line to further examine your data.

To remove the Examine line, click or tap Delete Examine Tool, ✕, displayed next to the line.



When viewing multiple graphs, the Examine line displays on all graphs referencing the same independent variable.



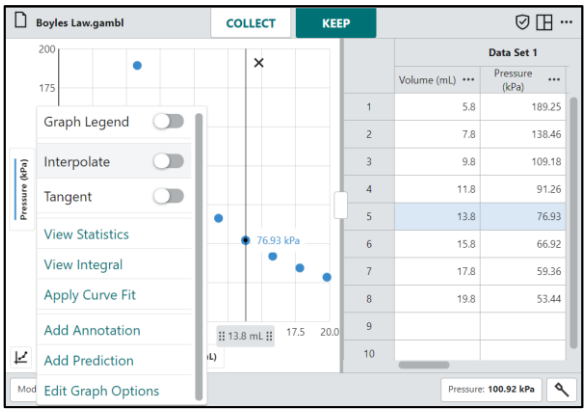
II. Interpolating and Extrapolating Data

To examine values between and beyond your data points, click or tap Graph Tools, , and turn on Interpolate.

The interpolate function affects the behavior of the examine cursor when examining data.

While Interpolate is turned off, the displayed examine values are for plotted data points. As you move the Examine line, the value of the nearest data point is displayed.

TIP! *You cannot use Interpolate and Tangent at the same time. Choosing one deselects the other.*

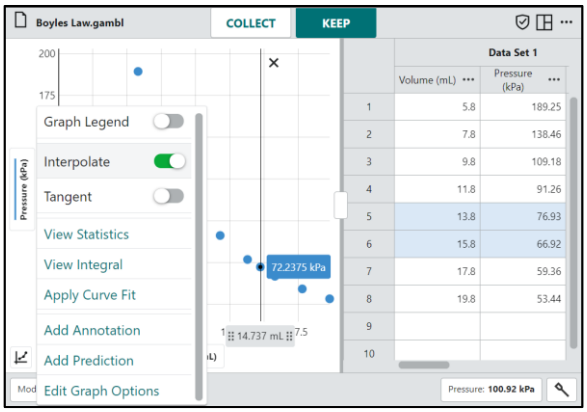


Interpolate Data

While Interpolate is turned on, you can estimate values between plotted data points. The values displayed depend on whether or not you have a curve fit plotted on the graph.

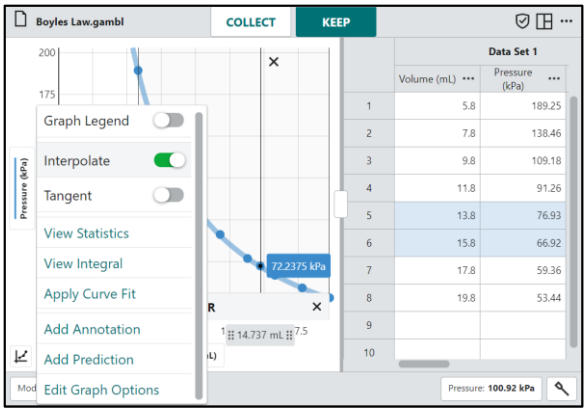
Interpolate Without a Curve Fit

When there is no curve fit, the examine cursor follows the straight-line path between two consecutive points.



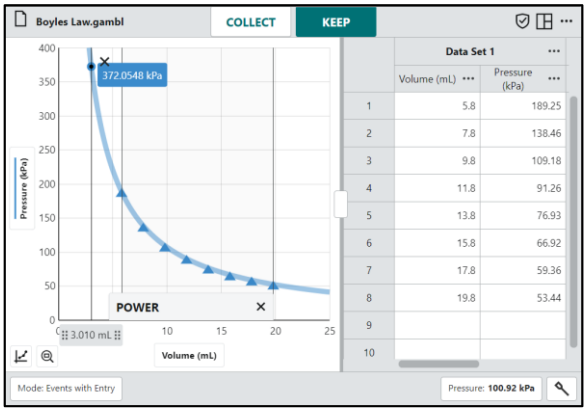
Interpolate with a Curve Fit

When there is a curve fit, examine follows the curve fit model to determine the examine values.



Extrapolate Data

To examine data beyond your data points (extrapolate), you must have a curve fit plotted on the graph and Interpolate turned on.



III. Exploring Rate of Change (Tangent)

To find the rate of change of your data at any point, click or tap Graph Tools, , and turn on Tangent.

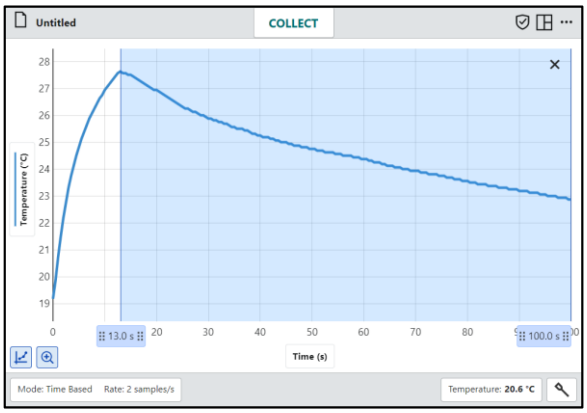
The tangent tool calculates the rate of change of the data (slope) at the examined point. The tangent value is determined based on the points immediately around the examined point.

TIP! *You cannot use Interpolate and Tangent at the same time. Choosing one deselects the other.*

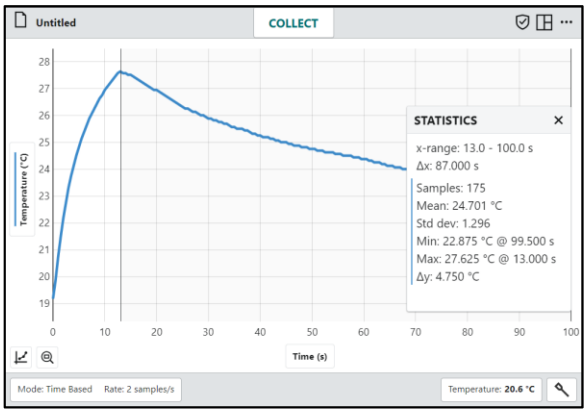
IV. Viewing Statistics

Use the Statistics tool to calculate statistical attributes based on your data. Displayed values include number of points, mean, standard deviation, minimum, maximum, and range. Statistics for all plotted columns are calculated.

If desired, select a region of data. If a region of data is not selected, the statistics tool uses all data in the calculation.



Click or tap Graph Tools, , and select View Statistics. Statistics for all plotted columns on the graph are calculated and displayed in the Statistics details box.



To dismiss the Statistics box, click or tap Close, .

TIP! *You can slide the Statistics box along the right region boundary if needed.*

V. Viewing Integral

Use the View Integral tool to calculate the numerical integral (area) associated with your data.

Select a region if desired. Click or tap Graph Tools, , and choose View Integral to find the integral. The associated area is shaded, and the value is displayed.

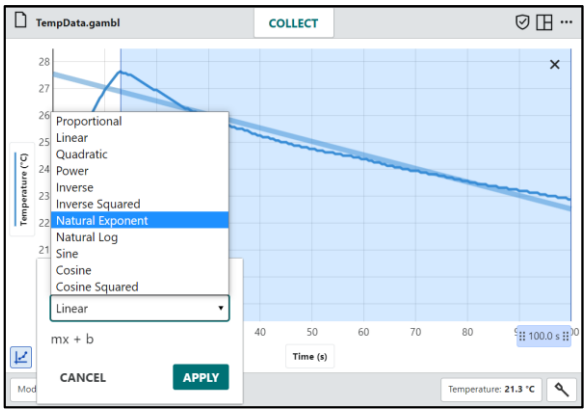
***TIP!** Regions above the horizontal axis (x-axis) are positive, while regions below are negative. Areas for all plotted columns are calculated and displayed in the Integral details box.*

VI. Applying a Curve Fit

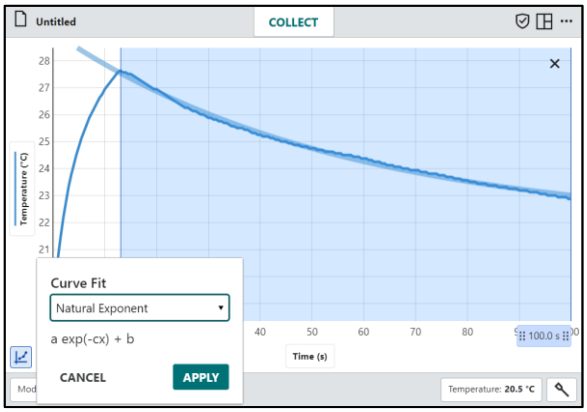
Use the curve fit tool to find a mathematical model that fits your data. Select a region first to fit a section of your data. When you select the tool without first selecting a region, all of the data are used to determine the fit model.

Click or tap Graph Tools, , and choose Apply Curve Fit to find the equation of the best-fit curve based on your data.

Curve fit models include Proportional, Linear, Quadratic, Power, Inverse, Inverse Squared, Natural Exponent, Natural Log, Sine, Cosine, and Cosine Squared.



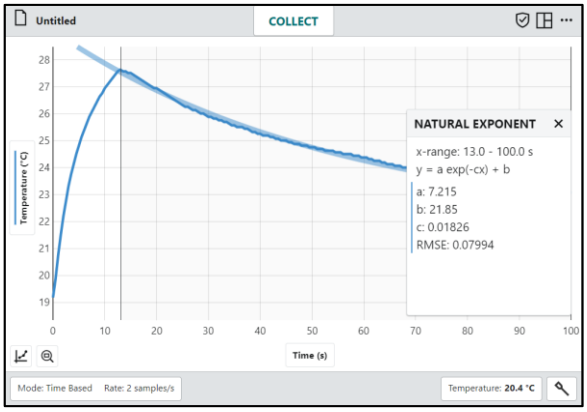
Choose a curve fit model to preview the fit to your data.



***TIP!** If you have the Graphical Analysis Pro features unlocked, you can fit your data using a custom expression. For more information, see Customized Curve Fits in Chapter 8.*

Click or tap **APPLY** to display the curve fit equation and coefficients. Curve fits for all plotted columns are calculated.

The curve fit details box includes the RMSE (root mean square error), a measure of how well the fit matches the data. Linear curve fits also show the correlation coefficient (*r*) associated with the linear fit.



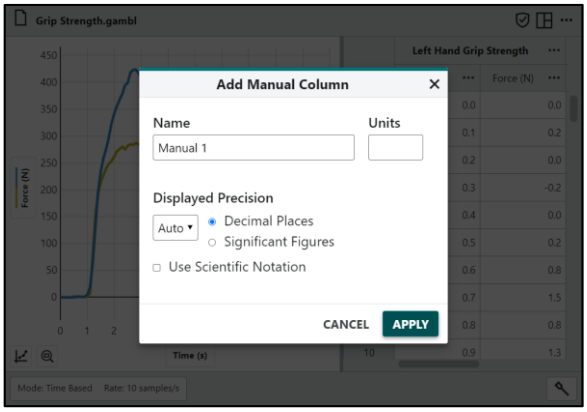
VII. Adding Additional Columns

Adding a Manual Column

Add manual columns to bring in data from other files or data found on the internet to compare with your data.

From the data table or Plot Manager, click or tap Column Options, ⋯, next to an existing column name. Choose Add Manual Column to create a new manual entry column.

You can modify the column name, add units, and adjust the display precision of the new column as desired. For instruction on entering data in this column, see Entering Data in a Data Table in Chapter 4.

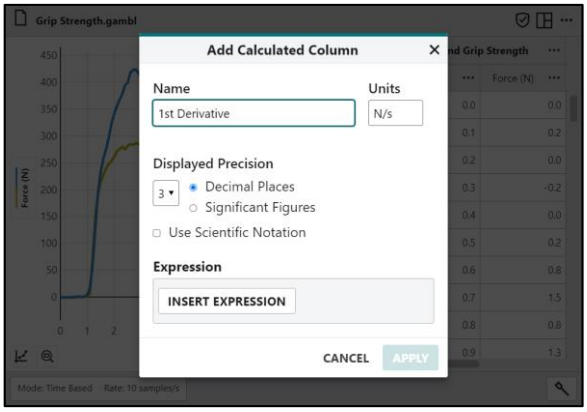


Adding a Calculated Column

Calculated columns are columns with values that are based on other columns through a mathematical formula. For example, you might define a calculated column as the inverse square of another column, or you might calculate the ratio of mass and volume columns to create a density column, or you might use calculated columns to create potential and kinetic energy columns from motion sensor data columns.

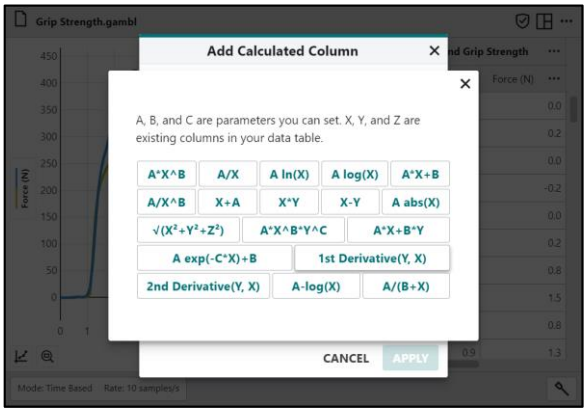
From the data table or Plot Manager, click or tap Column Options, •••, next to an existing column name. Choose Add Calculated Column to create a new column.

You can modify the column name, add units, and adjust the display precision of the new column as desired.



Click or tap **INSERT EXPRESSION** to view your expression options. Select the desired expression to use for your calculated column.

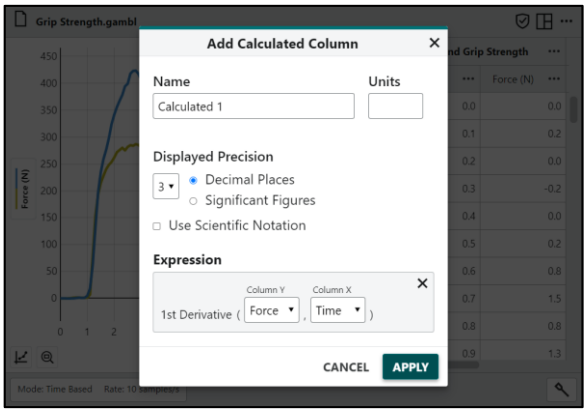
NOTE: A, B, and C represent constants. X, Y, and Z represent data columns from your data table.



TIP! *When the Graphical Analysis Pro features are unlocked, you can use user-defined expressions in your calculated columns. See Custom-Expression Calculated Columns in Chapter 8.*

The column from which you accessed the Column Options is used in the calculated column expression by default. Adjust the columns and parameters as desired.

Click or tap **APPLY** to create the column. The new calculated column appears to the right of the column used to access the Column Options.

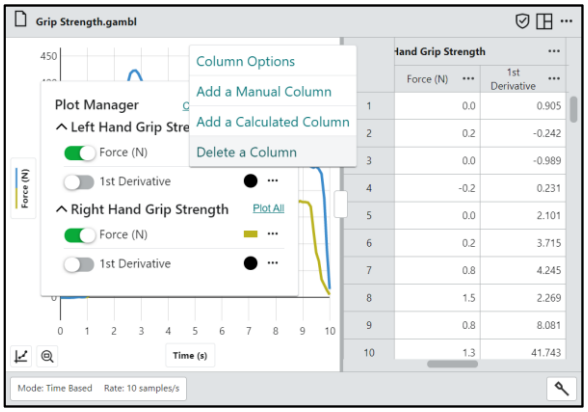


TIP! *To edit a calculated column once it has been created, click or tap Column Options, •••, next to the column name in the data table or Plot Manager and select Column Options.*

VIII. Managing the Data

Deleting Columns

From the data table or Plot Manager, click or tap Column Options, •••, next to an existing column name. Choose Delete Column to remove Manual or Calculated Columns. Sensor and time columns cannot be deleted.

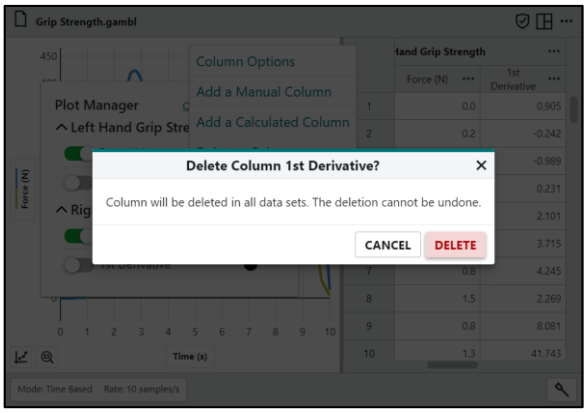


Click or tap **DELETE** to confirm the deletion. Deleting a column cannot be undone.

TIP! *Since data sets are symmetric, deleting a column from one data set removes the corresponding column from all data sets.*

Deleting Data Sets

From the data table, click or tap Data Set Options, •••, next to an existing data set name. Choose Delete Data Set to remove a data set.



Click or tap **DELETE** to confirm the deletion. Deleting a data set cannot be undone.

TIP! *The last created data set cannot be deleted; however, any entered or collected data are cleared.*

CHAPTER 7—MANAGING GRAPHICAL ANALYSIS FILES

I. Opening Files

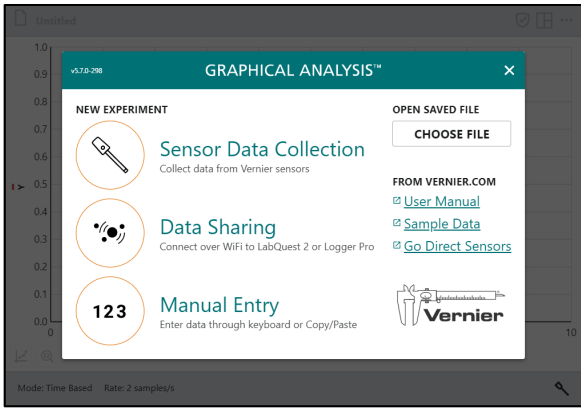
Click or tap the File menu, Untitled, and choose Open to display the Open file box. From here, you can access files stored on your device, from an accessible cloud storage location such as Google Drive™, iCloud®, or Dropbox, or from a connected storage device such as a USB drive or SD card.

Note: Not all options are available on every platform. You can choose to open previously saved Graphical Analysis (.gambl or .ambl) files or comma separated value (.csv) files.

Accessing Sample Data in Graphical Analysis

Click or tap the File menu, Untitled, and choose New Experiment. Choose Sample Data to launch the default browser with online access to sample data files for Graphical Analysis.

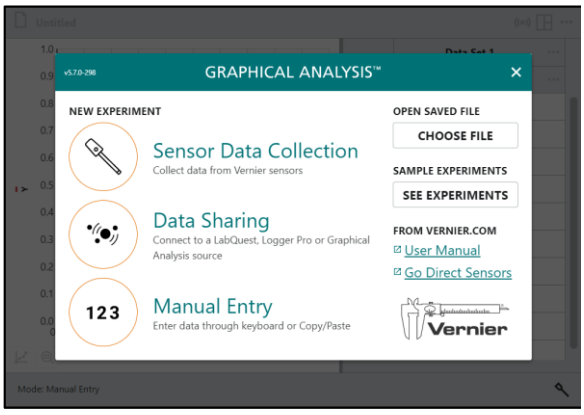
Sample files include data for Boyle's Law, Ball Toss, Plant Transpiration, and Periodic Trends.



Accessing Sample Data in Graphical Analysis Pro

If you have unlocked the Graphical Analysis Pro features, you can access over 40 data-collection experiments that include both data and videos.

Click or tap SEE EXPERIMENTS to access the files. For more information on using the files, see Accessing Sample Data Experiments in Graphical Analysis Pro in Chapter 8.



TIP! *To access the sample data files available when the Graphical Analysis Pro features are locked, select the User Manual option listed under* FROM VERNIER.COM. *This accesses a web page that includes those sample files.*

II. Saving Files

Save

Click or tap the File menu, Untitled, and choose Save to save the current file. This action replaces the previously saved file with the current file (in the same file location) without user confirmation. If your file has never been saved, selecting Save is equivalent to selecting Save As.

Save As

Click or tap the File menu, Untitled, and choose Save As to display the Save file box. You can name the file and select where the file is to be stored. You can save the file directly to your device, to an accessible cloud storage location such as Google Drive, iCloud, or Dropbox, or to a connected storage device such as a USB drive or SD card. **Note:** Not all options are available on every platform. Save As will not automatically overwrite a previously saved file.

III. Exporting Files

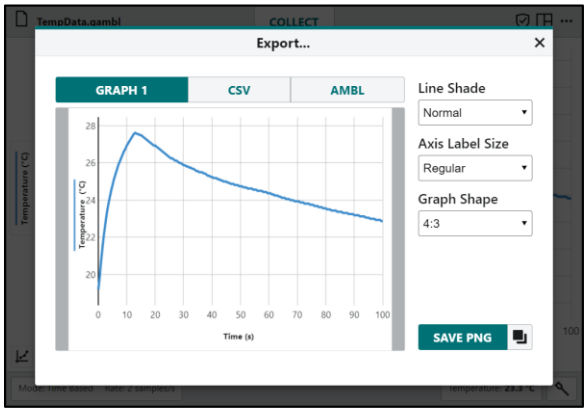
Click or tap the File menu, Untitled, and choose Export. You can choose to export graphs as .png files, data as .csv files, or Logger *Pro* compatible AMBL files.

Graph Files (.png)

Graph 1 is selected by default. When exporting a graph, you can select several options to enhance the exported graph file.

- **Line Shade**—this option controls how dark the graph grid and axis lines are drawn.
- **Axis Label Size**—this option controls the font size used for the axis labels.
- **Graph Shape**—this option controls the aspect ratio of the graph image.

TIP! *Changes to the above settings are reflected on the displayed graph.*

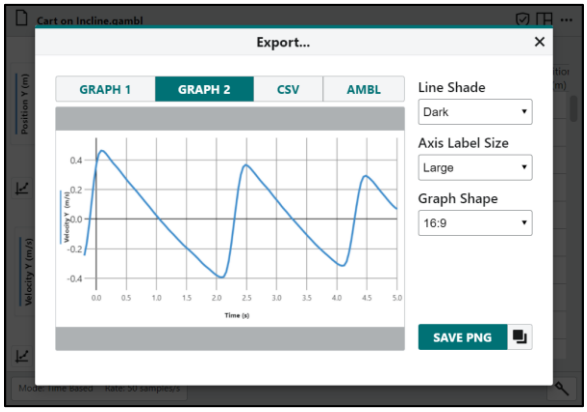


Click or tap SAVE PNG to save the graph file.

TIP! *You can click or tap Copy to Clipboard, , to copy the selected graph to your device clipboard. Use this feature to paste your graph into a document on your device.*

If you are displaying multiple graphs, you must export each graph separately. Style choices made for your first graph will persist for your other graphs.

TIP! *Use this feature to create images of your data for inclusion in a lab report or for submission to an instructor via file sharing, emailing, or printing.*

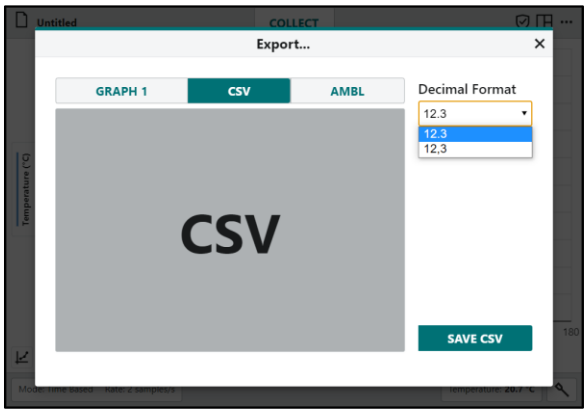


Data File (.csv)

Choose the CSV option to export your data for printing your data table.

Select the appropriate decimal separator for your data, then click or tap **SAVE CSV** to save the file.

TIP! *Use this feature to save the data in* .csv *format for further analysis with a spreadsheet application or to print your data.*

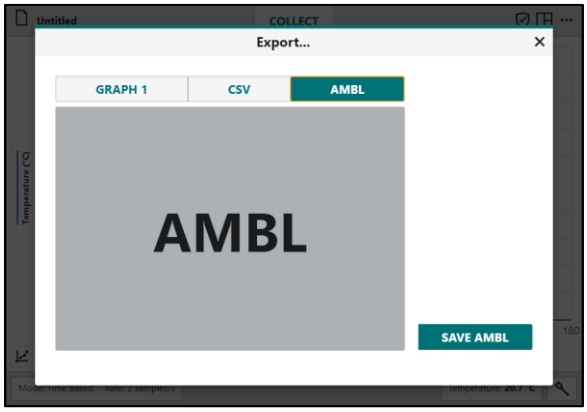


Legacy Data File (.ambl)

Choose the AMBL option to export the data as an .ambl file.

Click or tap **SAVE AMBL** to save the file.

TIP! *Use this feature to create a data file that you can open in our Logger* Pro *3 computer software.*



IV. Printing from Graphical Analysis

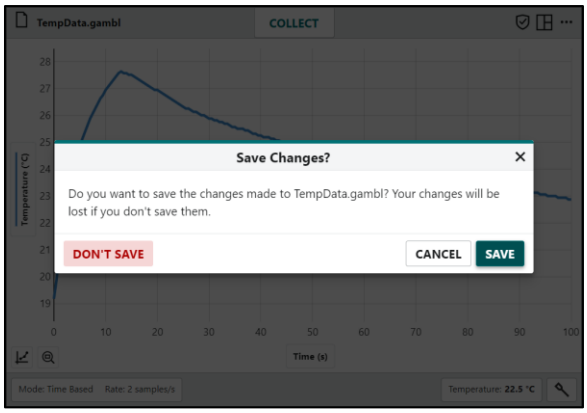
You cannot print directly from Graphical Analysis. To print a Graphical Analysis file, use File ▸ Export to create the desired file (.csv or .png). Print the resulting file using the print options available on your device.

TIP! *For more information regarding printing from Graphical Analysis, see* www.vernier.com/til/3789

V. Starting a New Experiment File

Click or tap the File menu, Untitled, and choose New Experiment to start a new file and reset all data-collection parameters. If you have unsaved data, you will be prompted to save the existing file before continuing.

TIP! *Wireless sensors already connected when selecting New Experiment remain connected when the new experiment is created.*

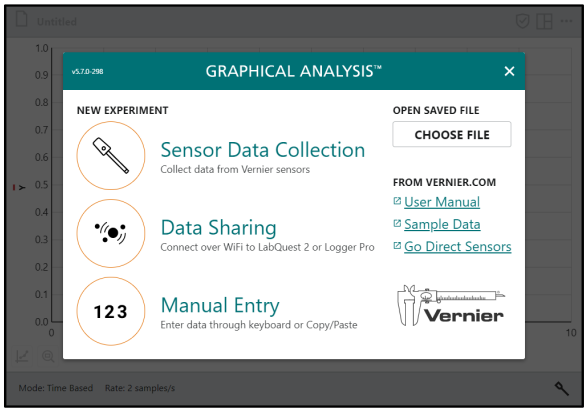


CHAPTER 8—GRAPHICAL ANALYSIS PRO

I. Unlocking Graphical Analysis Pro Features

Follow these steps to unlock the Graphical Analysis Pro features.

1. Launch Graphical Analysis app and select a 123 Manual Entry experiment.



2. Click or tap GA Pro Authorization, .

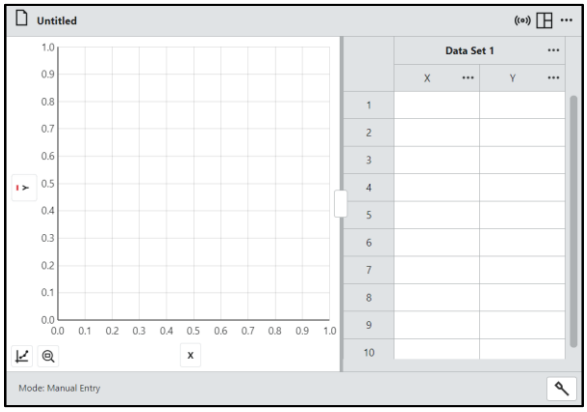
3. Enter your GA Pro License Key provided to you by Vernier. The authorization key is case sensitive and must be entered exactly as it appears.

   TIP! *Instructors will need to distribute the authorization key to their students. Vernier will not distribute license keys to students.*

4. Click or tap **SUBMIT** to unlock the Graphical Analysis Pro features.

   Note that the GA Pro Authorization button, , is replaced by the Data Sharing button, .

   TIP! *If this is the first time you are using the license key, you may be prompted to accept the End Users License Agreement before you can use the Graphical Analysis Pro features. This must be done using the email address of the person to whom the subscription is issued.*



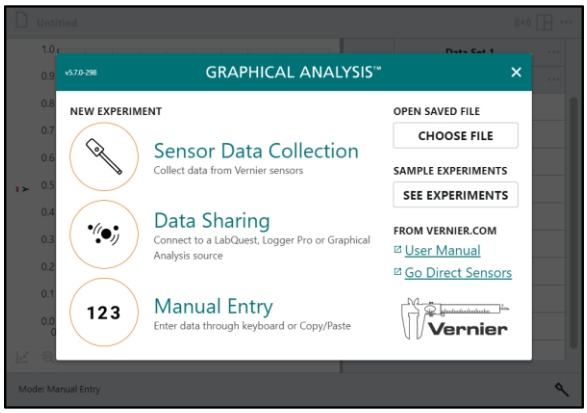
II. Accessing Sample Experiments in Graphical Analysis Pro

Graphical Analysis Pro comes with over 40 experiment files that are perfect for pre-experiment exercises, independent study, or post-experiment enrichment. The experiments, taken from our popular lab books, include a video of one of the data-collection trials. Experiments are available for middle school, biology, chemistry, and physics.

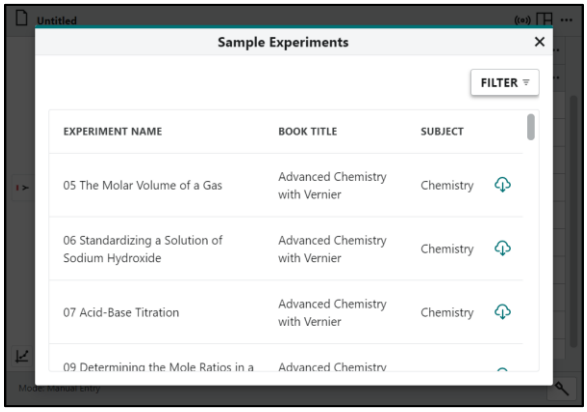
Below are instructions for accessing and using these files. Note that you must unlock the Graphical Analysis Pro features in order to access the files.

1. Launch Graphical Analysis Pro.

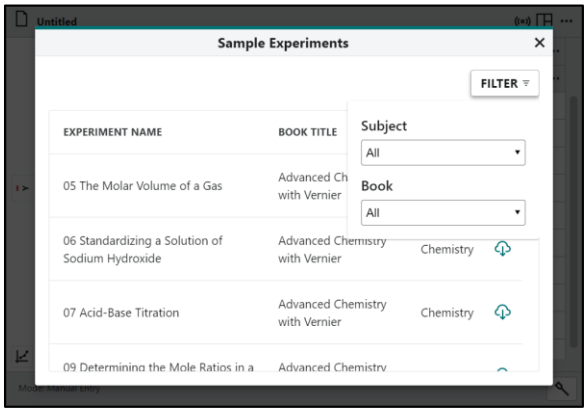
   TIP! *If you are already running Graphical Analysis Pro, click or tap the File menu, Untitled, and choose New Experiment to access the New Experiment box.*



2. Click or tap **SEE EXPERIMENTS** to access the experiment files.

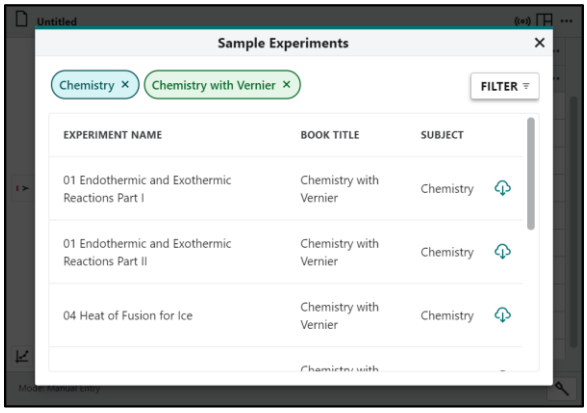


3. Click or tap **FILTER** to quickly find experiments for a specific subject area and/or from a specific book.



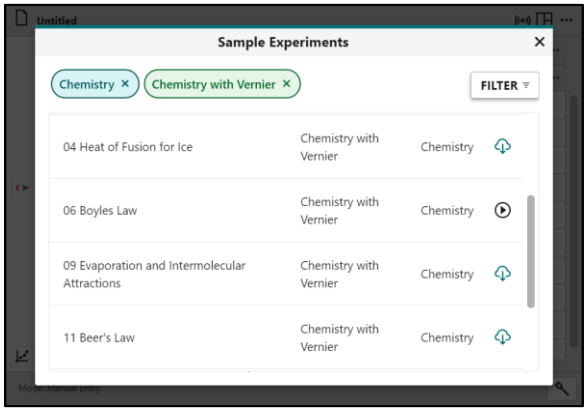
4. Click or tap the Subject or Book dropdown list, All, and choose the appropriate filter.

   TIP! *You can apply multiple filters if desired.*



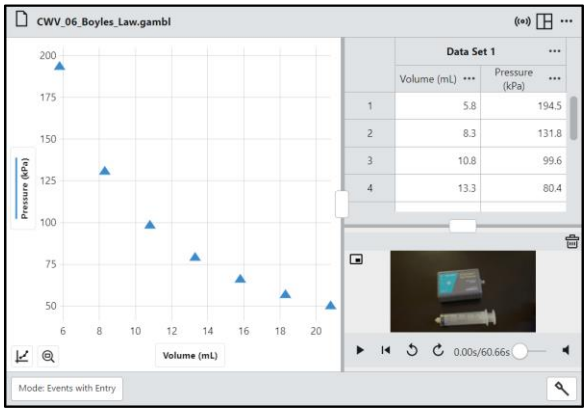
5. Browse the list of experiments and locate the file you want to open.

   TIP! *You must have a live internet connection to access these files.*



6. Click or tap Download, , to download and open the experiment file.

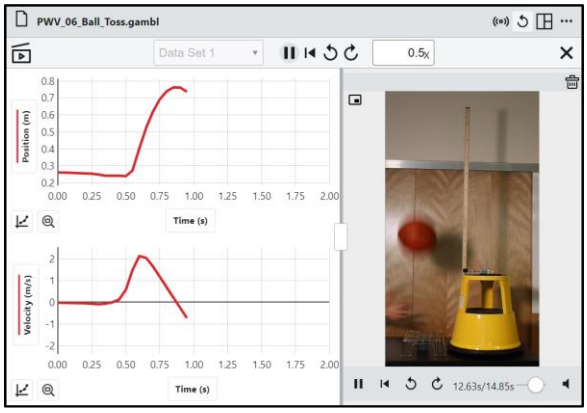
   TIP! *If you have previously viewed a file, the Download button, , is replaced by a Play button, .*



   If the experiment file you open includes time-based data, the included video and data from one of the trials are synced.

   Click or tap Enable Replay, , to access the replay data-collection controls. Click or tap Start Replay, , from the replay data toolbar to replay both the data and synched video.

   For more information, see Replaying Data Collection.



III. Data Sharing with Graphical Analysis Pro

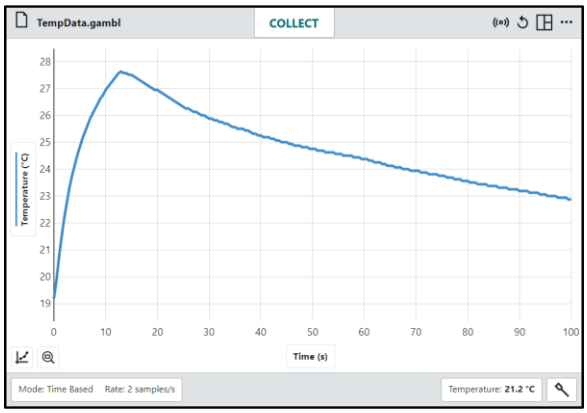
Graphical Analysis Pro can serve as a Data Sharing source that can wirelessly stream sensor data to another device that is also running Graphical Analysis Pro. Use Graphical Analysis Pro to data share lecture demonstration data with your in-person class or with students studying remotely, so they can independently analyze the data. Students in lab groups can also data share with their lab partners so everyone in the lab group has a copy of the data.

Setting up Graphical Analysis Pro as the Data Sharing Host

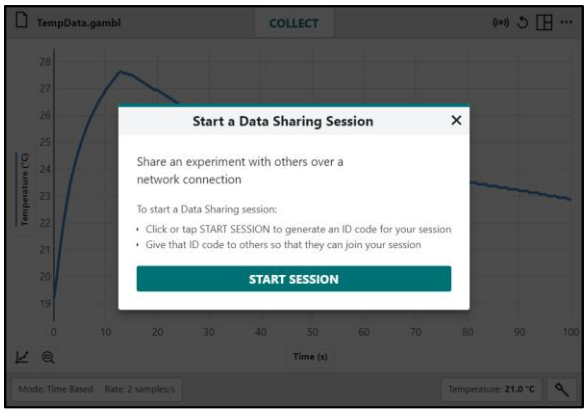
1. Make sure your device has a live internet connection.

   Launch Graphical Analysis and set up a sensor data-collection experiment using sensors.

   TIP! *It is not necessary to collect data before setting up a Data Sharing source; however, if data have already been collected, devices get that data when they connect, confirming the connection is successful.*

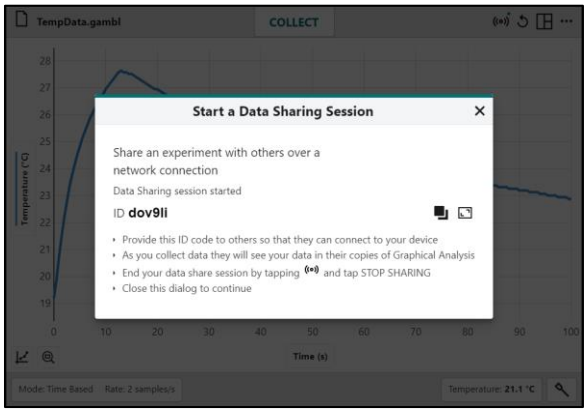


2. Click or tap the Data Sharing,  , to access the data sharing setup box.



3. Click or tap **START SESSION** to initiate data sharing from your device. A unique six-character ID code is generated. Share this code with everyone to which you are data sharing.

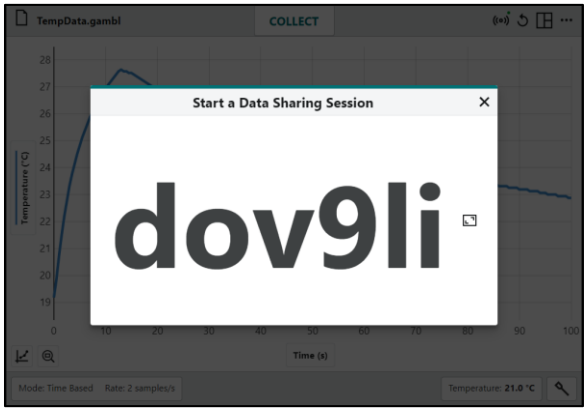
   TIP! *The ID code consists of five lower-case letters and a number (e.g., abc4ef; the fourth character is always a number).*



4. Click or tap Full Screen, , to display the code full screen. This is useful if you are displaying your screen live.

   Click or tap Full Screen, , again to exit the full-screen display of the code.

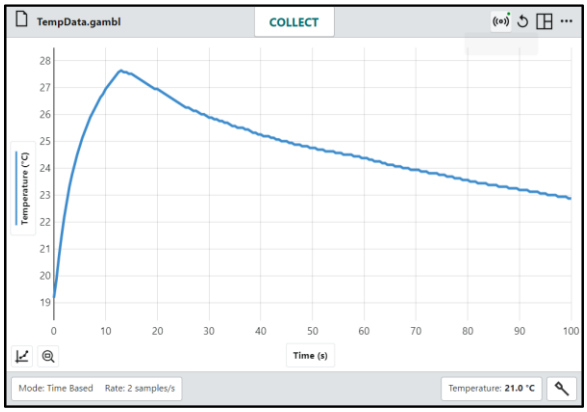
   TIP! *You can also click or tap Copy, , to copy the code to your device clipboard. Use this feature to paste the code in an email, text message, or meeting chat for sharing with others.*



5. Click or tap Close, , to exit the setup screen and continue with your experiment.

   Note that the Data Sharing button now has a green dot, . This indicates that your device is actively sharing data.

   TIP! *Click or tap Data Sharing, , to access the data sharing ID again or to see how many devices to which you are currently data sharing.*



6. Click or tap **STOP SHARING** to end the data sharing session.

   TIP! *The data share ID number changes every time you start a new data sharing session. If you stop sharing inadvertently, you need to send out the new data sharing ID after you start the new session.*

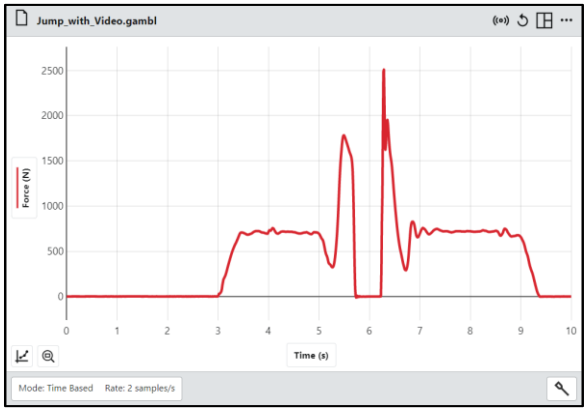
Connecting to a Graphical Analysis Pro Data Sharing Source

See Connecting to a Graphical Analysis Pro Data Sharing Source in Chapter 3.

IV. Replaying Time-Based Data Collections

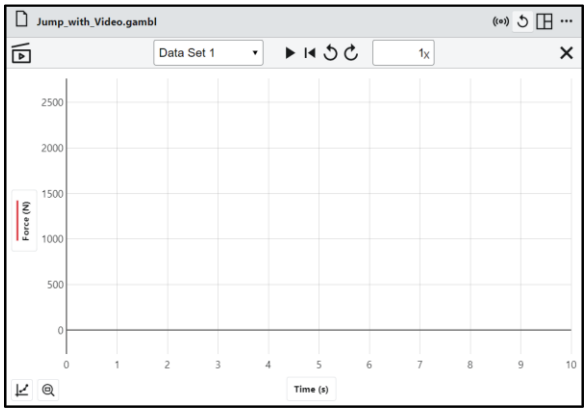
Graphical Analysis Pro provides the tools to replay data from a time-based data collection. This feature is only available for time-based sensor data and is most useful when paired with a video synced to the collection. For more details, see Syncing a Video to a Time-Based Data Collection.

1. Collect some time-based sensor data or open a data file containing time-based sensor data. Notice that Enable Replay, , is shown on the top bar.

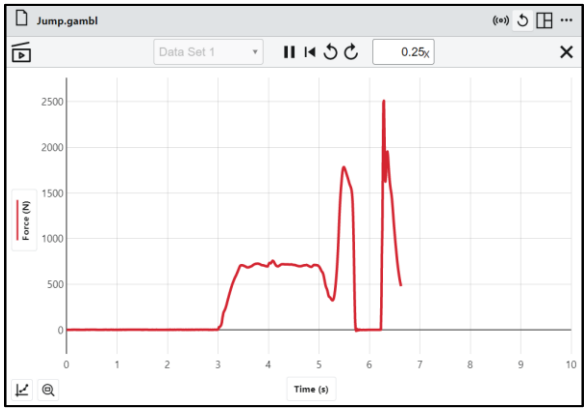


2. Click or tap Enable Replay, , to access the replay tools. This sets the replay time to zero, hiding the collected data.

   TIP! *If you have more than one data set, click or tap the data set dropdown menu to select the data set you want to replay. If you change data sets, be sure the data set you want to replay is selected to plot on your graph.*



3. Click or tap Playback Speed, 1x, to set the data-collection replay speed. Maximum replay speed is 1000× normal speed. To make the replay slower than normal, enter a value between 0 and 1.



   - Click or tap Start Replay, , to replay the data collection.
   - Click or tap Pause Replay, , to pause the replay.
   - Click or tap Restart Replay, , to replay the collection from the beginning.
   - Click or tap Step Backward, , and Step Forward, , to rewind or advance the replay by one time-unit.
   - Click or tap Close Replay, , to exit replay.

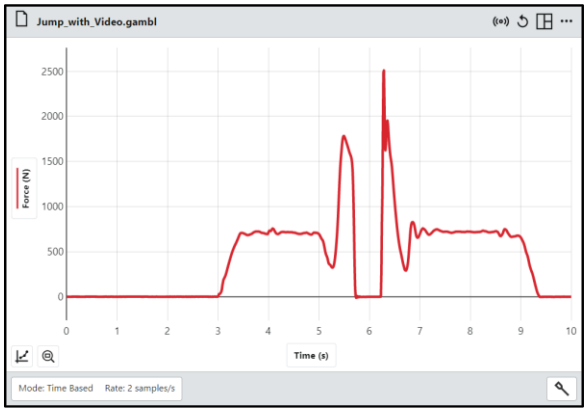
Sync Video to Data, , is used for syncing data-collection replay to a video. For more information, see Syncing a Video to a Time-Based Data Collection.

V. Adding a Video to a Graphical Analysis Pro Data File

You can enhance your Graphical Analysis data file by including a video of your experiment. Capture the video using your computer camera or phone, and import the video into Graphical Analysis Pro.

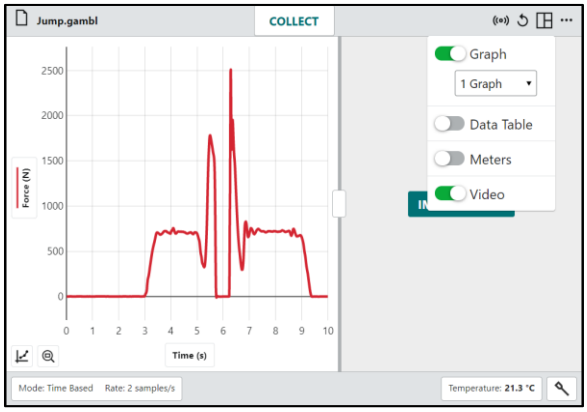
Videos of time-based data collection experiments can be synchronized with the data collection in Graphical Analysis Pro. For more information, see Syncing a Video to a Time-Based Data Collection.

1. Start a new data file or open an existing file.



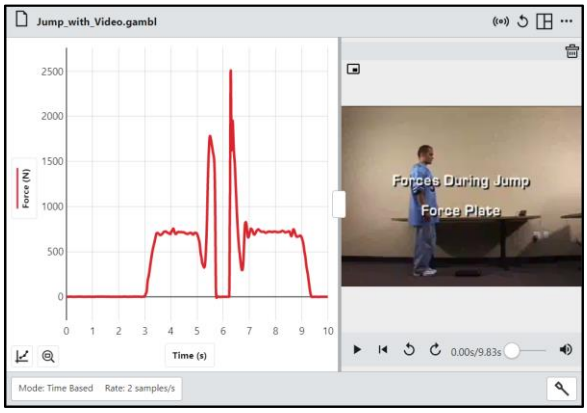
2. Click or tap View Options, , and turn on Video.

   TIP! *You must have the Graphical Analysis Pro features unlocked to display a video.*

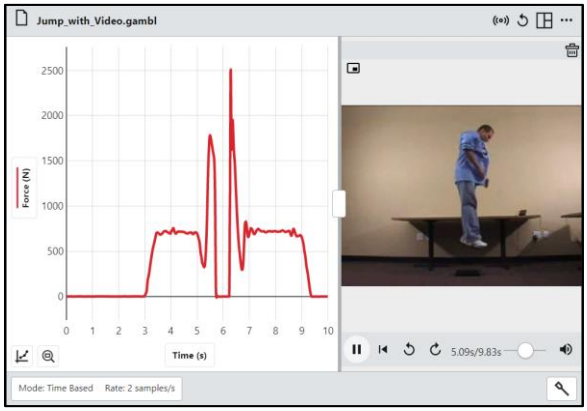


3. Click or tap **IMPORT VIDEO**, browse to the video on your device, and import it.

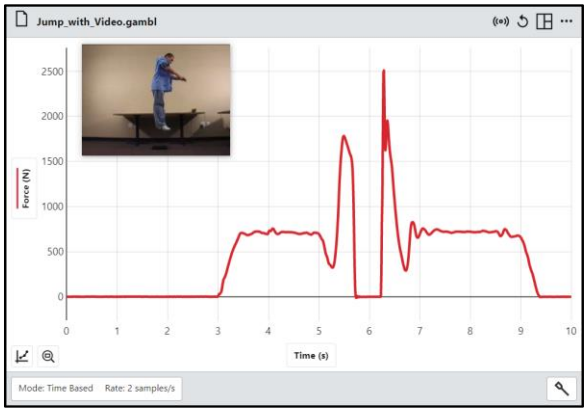
   TIP! *You can resize the split between the video and the graph as needed by dragging the handle on the separator bar,* .



4. Use the replay tools, as indicated below.



- Click or tap Start Replay, ▶, to play the video.
- Click or tap Pause Replay, ⏸, to pause the video.
- Click or tap Restart Replay, ⏮, to replay the video from the beginning.
- Click or tap Step Backward, ↺, and Step Forward, ↻, to rewind or advance the video frame by frame.
- Control the video manually by adjusting the video slider, —○—.
- Click or tap Audio, 🔈, to play the video's audio track during playback. Click or tap Audio again, 🔊, to mute the audio during playback.



Click or tap the Picture-in-Picture, ⧉, to display the video in a floating display that you can resize and reposition. This feature is not available for all platforms and all operating systems.

To play the video from the picture-in-picture frame, click or tap the video and select Start Replay, ▶.

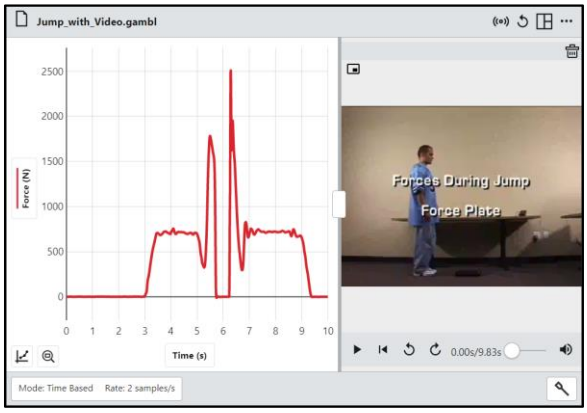
To exit the picture-in-picture mode, click or tap the video and select Close, ×.

Click or tap Delete Video, 🗑, to remove the video from the file.

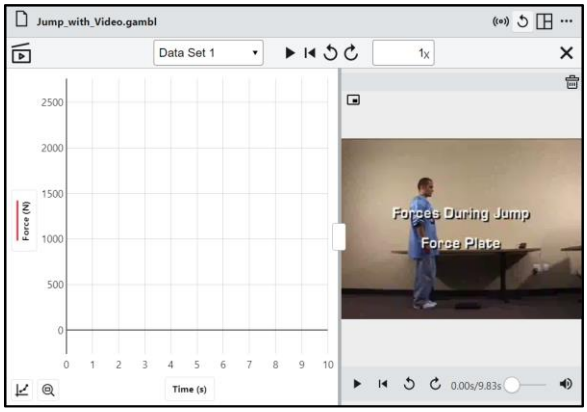
VI. Syncing a Video to a Time-Based Data Collection

1. Capture a video of a time-based sensor data-collection experiment and import the video into the Graphical Analysis Pro data file.

   For more information, see Adding a Video to a Graphical Analysis Pro Data File.

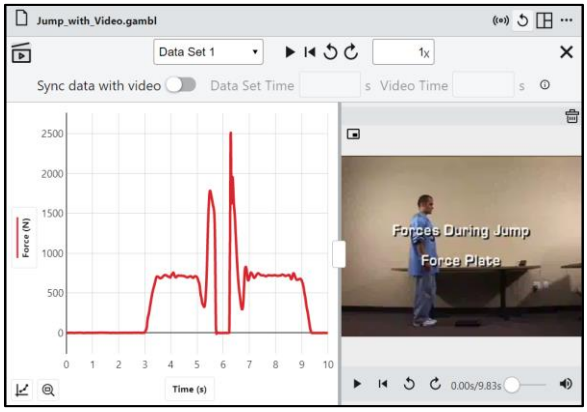


2. Click or tap Enable Replay, , to access the replay data-collection tools.



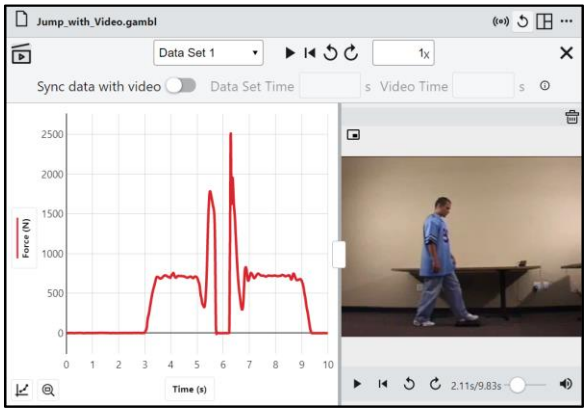
3. Click or tap Start Replay, , from the replay data toolbar to replay the data collection so you can again see all of the data.

4. Click or tap Sync Video to Data, , to access the sync video tools.

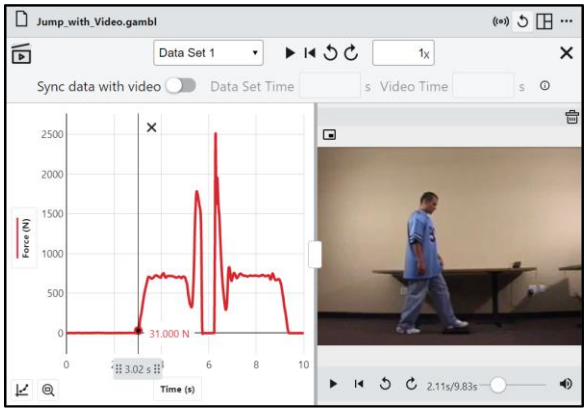


5. Advance the video to a frame that you can easily correlate to one of the data points.

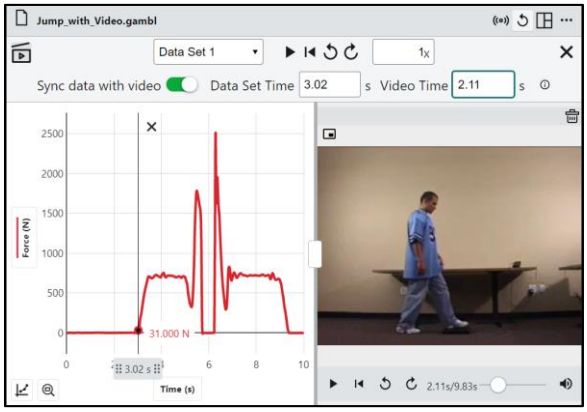
   For example, in the video shown here, the frame where the jumper first steps on the force plate correlates to a point where the force starts to increase.



6. Click or tap the graph at the point that corresponds to the video frame you have selected.



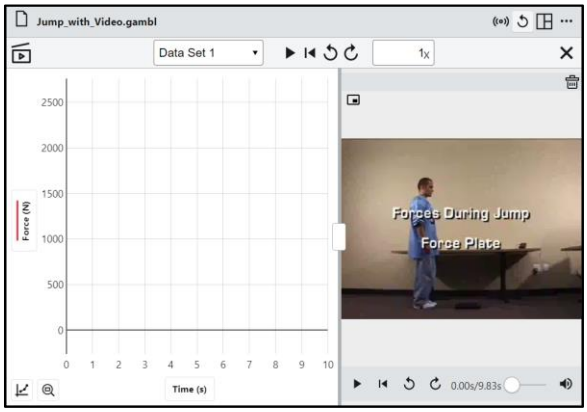
7. Click or tap Sync data with video, , to turn on the sync tool.
   - Enter the time associated with the examine line as the Data Set Time.
   - Enter the time associated with the current video frame as the Video Time.



8. Click or tap Sync Video to Data, , to close the sync video tool.

   Click or tap Restart Replay, , from the replay data toolbar. Note that because they are synched, both the data and the video reset to the start of data collection.

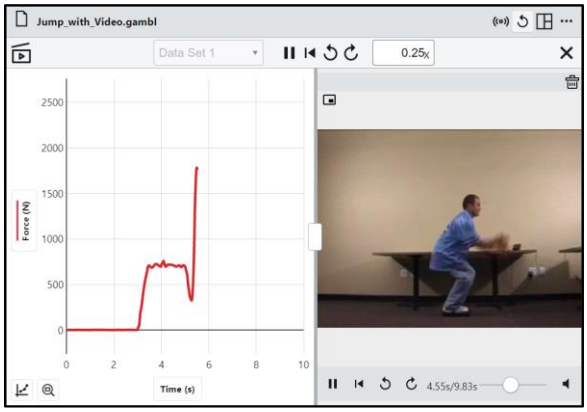
   TIP! *Using Restart Replay, , from the video tools only rewinds the video.*



9. Click or tap Playback Speed, 1x, and set the replay speed as desired. The maximum replay speed for a synced video is 16× normal speed.

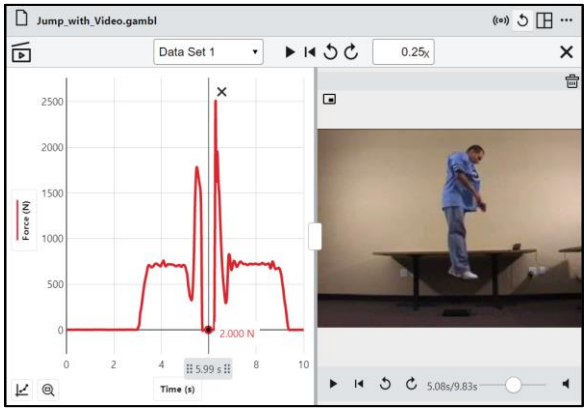
   Click or tap Start Replay, , from the replay data toolbar to replay the data collection and synched video at the same time.

   TIP! *Using Start Replay, , from the video tools only plays the video.*



10. When data collection is complete, you can tap to examine a data point and the corresponding video frame.

    TIP! *Because they are synched, dragging the examine line also controls the video so that the displayed video frame corresponds to the examined data point.*

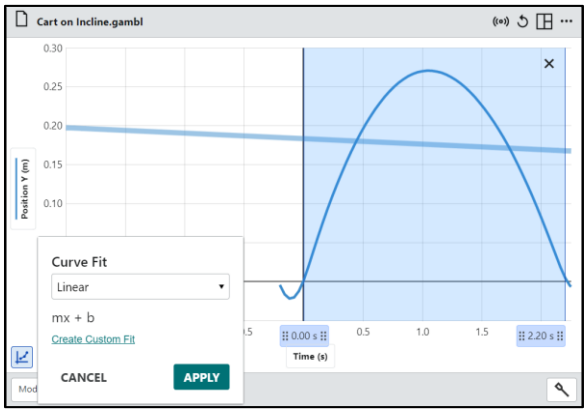


VII. Customized Curve Fits

You can create a custom curve fit expression by modifying an existing expression or entering a new expression. The independent variable, x, is used to represent the data column plotted on the horizontal axis. Parameter labels can be one or more letters (except x) and are case sensitive.

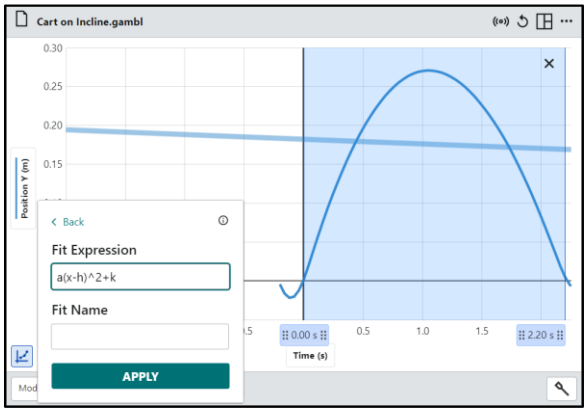
1. If desired, select a region of data, then click or tap Graph Tools,  , and choose Apply Curve Fit.

   TIP! *You can select a curve fit model with an expression that is most similar to the one you want to enter. This can make entering your expression easier.*



2. Click or tap Create Custom Fit to enter a custom fit expression. Modify the expression as needed.

   TIP! *You can click or tap Info, ⓘ, for in-app access to the details related to entering an expression.*



Supported Operators: + – * / ^ ( )

Supported Functions: exp( ), ln( ), log( ), sqrt( ), sin( ), cos( ), tan( )

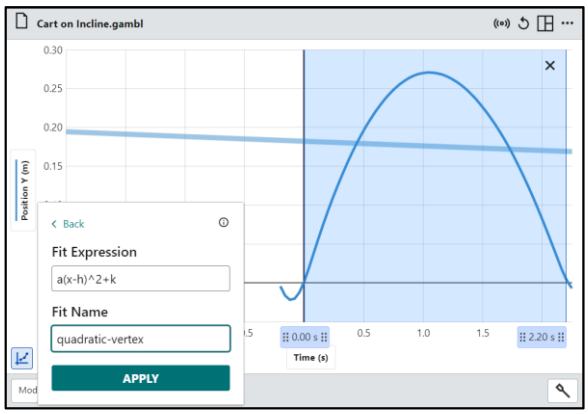
Example Expressions:

- **Modified Linear:** A + B*x **or** slope*x + intercept
- **Modified Quadratic:** A(x – h)^2 + k **or** A(x–a)(x–b)
- **Base-10 Exponent:** A*10^(Bx + C) + D
- **Gaussian:** A*exp(– (x–B)^2/C^2) + D

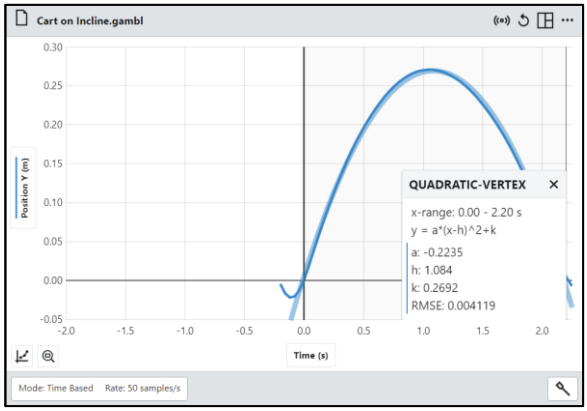
Expression Details:

- An expression must include the independent variable and at least one parameter.
- Functions and the independent variable must be lower case. [sin(x) not SIN(x) or sin(X)]
- There can be no more than six parameters in an expression.
- Multiplication can be explicit or implied. [A*x or Ax]
- Parameters cannot be repeated within an expression. [A(x + y) not Ax + Ay]
- Trigonometric functions are evaluated in radians except when the column plotted on the horizontal axis has units—°, deg, or degrees.

3. Add a name for your fit, if desired. If you do not add a name, the expression is used as the fit name.

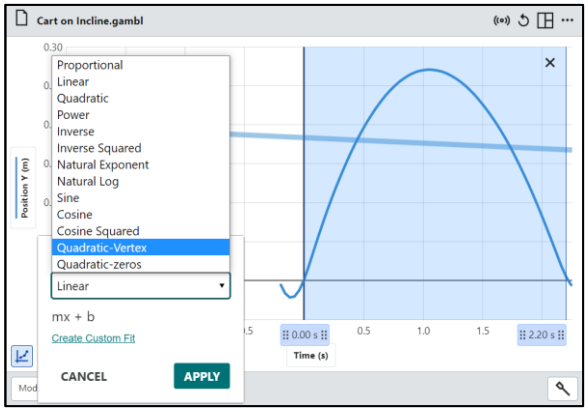


4. Click or tap **APPLY** to apply the fit you your data.



Once you have applied a custom fit to your data, you can use that curve fit expression to fit other data collected in the current file.

Custom curve fit expressions are saved along with the data and other experiment settings when you save the Graphical Analysis Pro (.gambl) file.



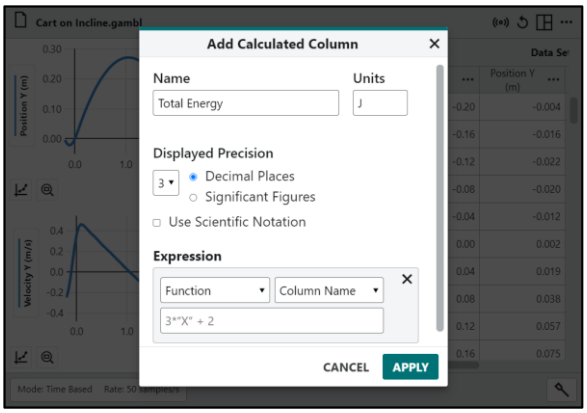
Note: Custom curve fits are only accessible in the file in which they are created. Starting a new experiment, opening a different file, or restarting the app will remove the custom curve fit from Graphical Analysis Pro.

VIII. Custom-Expression Calculated Columns

Calculated columns are columns with values that are based on other columns through a mathematical formula. With Graphical Analysis Pro, you can use specialized functions to define custom expressions when creating calculated columns. This functionality extends your options when defining the calculated column expression.

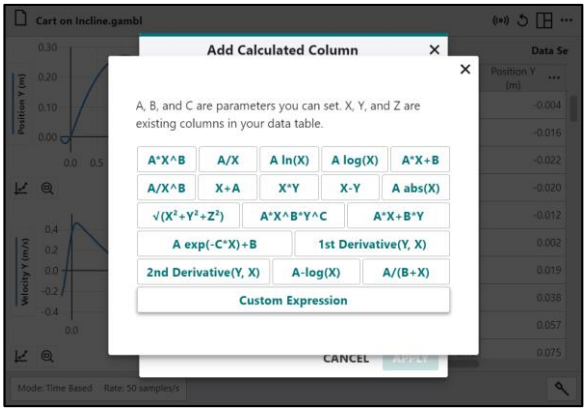
1. From the data table or y-axis Plot Manager, click or tap Column Options, ⋯, next to an existing column name. Choose Add Calculated Column to create a new column.

   You can modify the column name, add units, and adjust the display precision of the new column as desired.



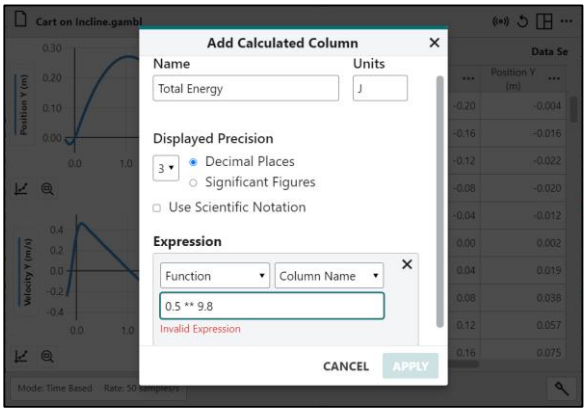
2. Click or tap **INSERT EXPRESSION** to view your expression options.

   Click or tap **Custom Expression** to create a custom expression.



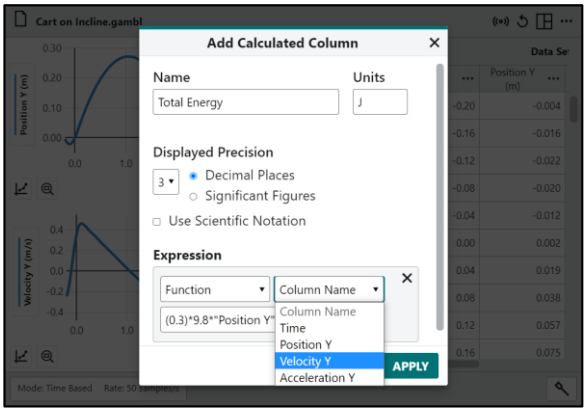
3. Enter the expression as desired.

   Note: The expression is checked for errors as it is entered. You must fix any errors before applying the expression.



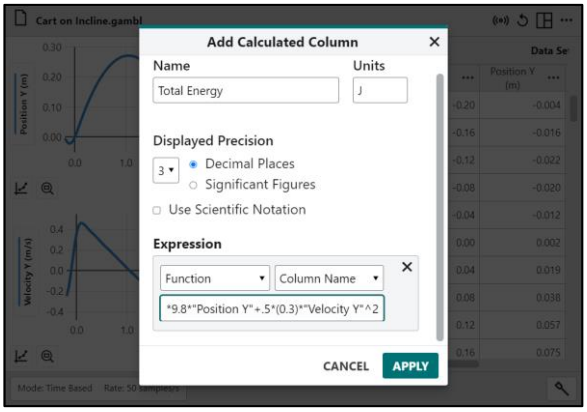
4. Click or tap **Column Name** ▾ to reference a column of data in the expression. The column name can be entered by hand, but it must be in quotes and exactly match the name as displayed in the data table or in the Plot Manager.

   TIP! *When there are multiple data sets, the column name refers to the column within that data set only.*



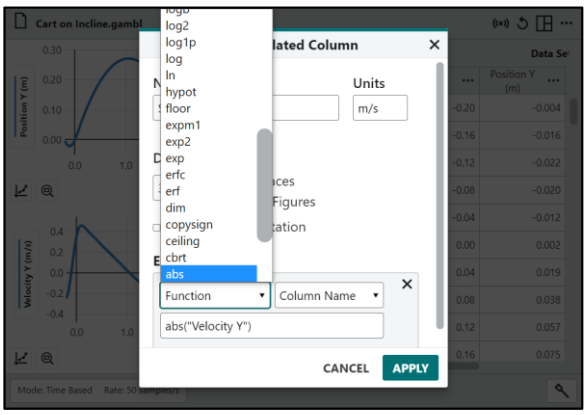
5. Click or tap APPLY to create the calculated column.

   TIP! *To edit a calculated column once it has been created, click or tap Column Options,* ••• *, next to the column name in the data table or y-axis Plot Manager and choose Column Options.*



When entering an expression, click or tap Function ▾ to access a library of functions available for your custom expression. Available functions include the following:

- Common math functions including square root, cube root, power, exponential, and logarithmic functions
- Trigonometric functions including inverse and hyperbolic trigonometric functions
- Number sense functions including absolute value, round, truncate, ceiling, floor, and modulo



Calculated Column Custom Expression Details

- An expression must be a number, a data column, an appropriately formatted function, or a combination of these items. [5, "X", sin("X"), or 5sin("X")]
- Supported operators are as follows: +, –, *, /, ^, (, and).
- Functions must contain their arguments in parentheses. [abs("X") or sqrt(2)]
- Multiplication can be explicit and implied. [5*"X" or 5"X" or 5("X")]
- Constants must be entered as numbers. Variable parameters (e.g., A, B, C) are not supported.
- Trigonometric functions are evaluated in radians.
- Functions can be nested as long as the proper format is used. [sqrt(abs("X"))]

For a complete list of functions and their syntax, see https://www.vernier.com/til/11314.

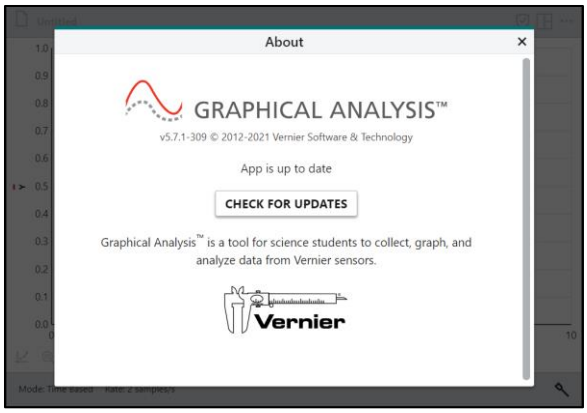
CHAPTER 9—APPENDIX

I. Updating Graphical Analysis

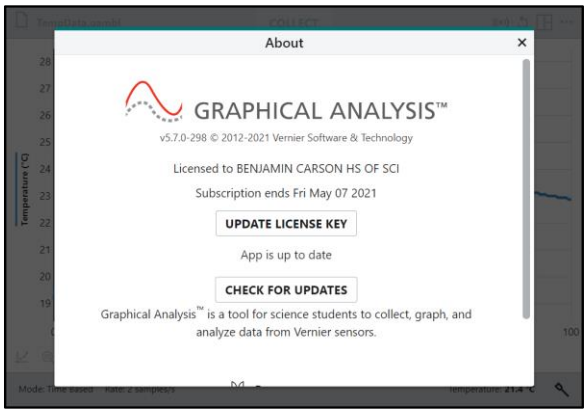
Determining Your Software Version

Click or tap Other Options, •••, from the top toolbar, and choose About to see what Graphical Analysis version you are running.

When using computers, the About box also provides a way to check for updates.



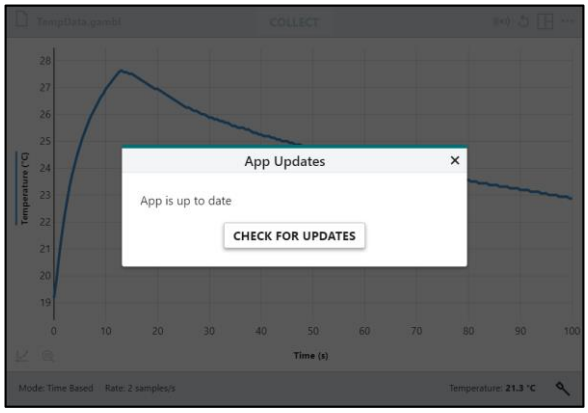
When you have unlocked the Graphical Analysis Pro features, the About box provides a way to update your Graphical Analysis Pro Key. For more information, see Updating the Graphical Analysis Pro Key.



Check for Updates (Computers Only)

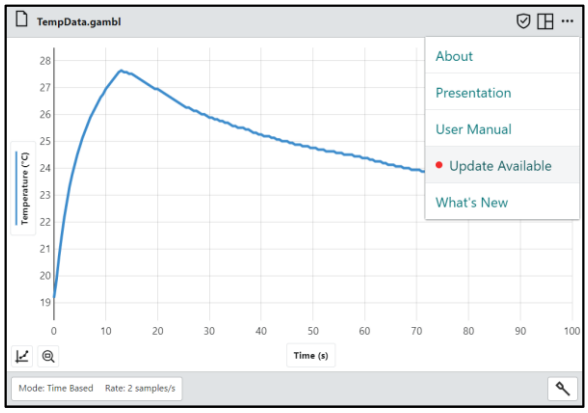
Click or tap Other Options, •••, from the top toolbar, and choose Check For Updates to ensure you are running the latest version of Graphical Analysis. You can choose to update if a newer version is available. This option requires your device to have an active internet connection.

TIP! *This option is displayed for computers only. Chrome OS, iOS, iPadOS, and Android versions automatically check for and apply updates.*



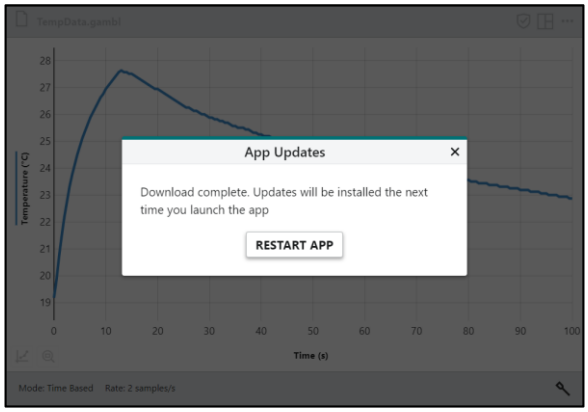
Graphical Analysis automatically checks for updates when your computer has an internet connection. When an update is available, the Check for Updates option is replaced with Update Available. Follow the steps below to update Graphical Analysis.

1. Click or tap Other Options, ••• , from the top toolbar and select ● Update Available.



2. Click or tap DOWNLOAD UPDATE to download the update.

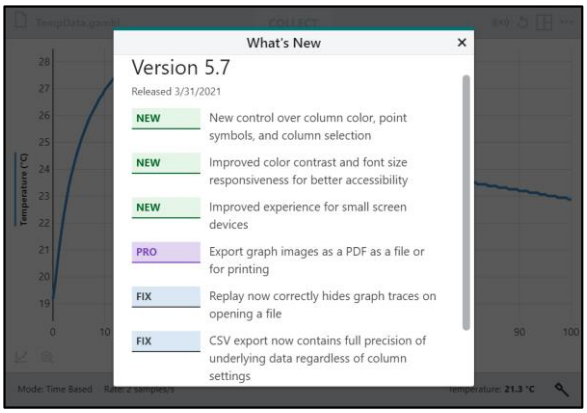
3. The app must restart for the update to install. Click or tap RESTART APP to complete the update.



What's New

Click or tap Other Options, ⋯, from the top toolbar, and choose What's New to view a summary of the new features and fixes available in the most recent version of Graphical Analysis.

Click or tap SHOW ALL RELEASES to see changes made in previous versions.

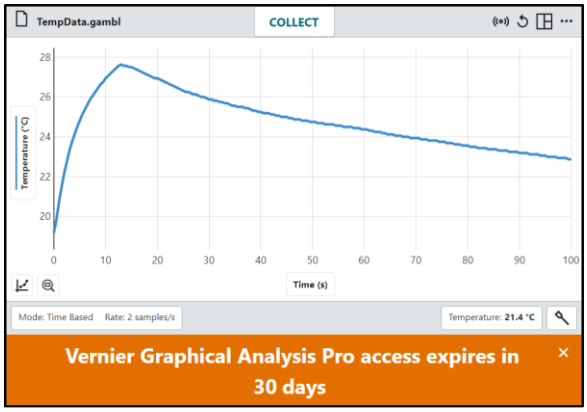


II. Updating the Graphical Analysis Pro Key

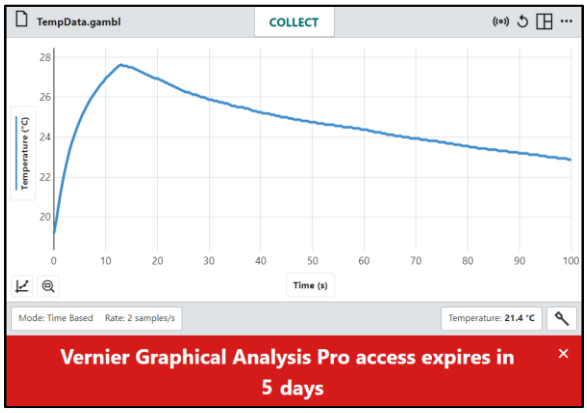
Graphical Analysis Pro features are subscription-based. Updating the key is required to continue using the software when a subscription expires.

30 days prior to the expiration of your current license key, an expiration reminder is displayed when you launch Graphical Analysis.

TIP! *This warning is always shown when using a 30-day free trial of Graphical Analysis Pro.*

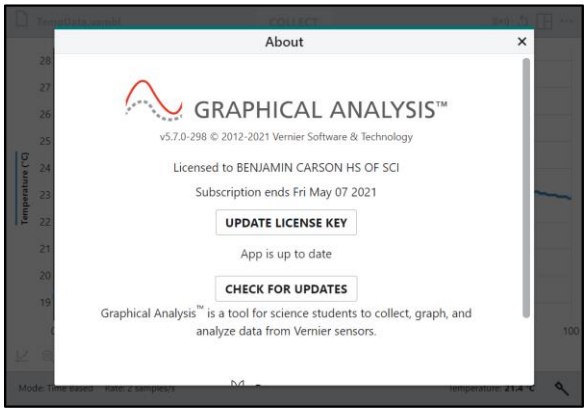


When you are within 15 days of expiration, the warning is displayed in red.



Follow these steps to update your Graphical Analysis key from a free trial to a paid subscription or to update an expiring subscription to a new subscription.

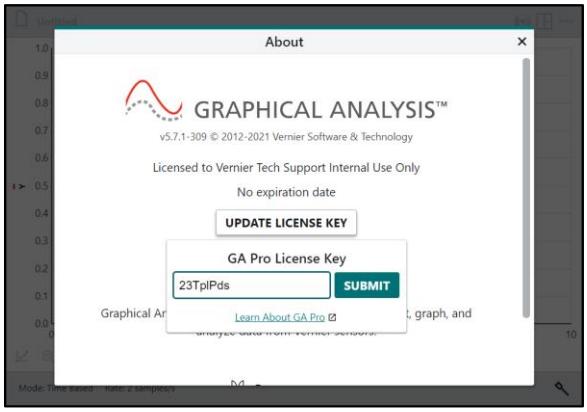
1. Click or tap Other Options, •••, from the top toolbar and choose About.



2. Click or tap **UPDATE LICENSE KEY**, enter the new key, and click or tap **SUBMIT**.

   You can continue to use the Graphical Analysis Pro features.

   CAUTION! *If you enter an invalid key, your Graphical Analysis Pro features again become locked. Enter a valid key or restart the app to continue to use the Graphical Analysis Pro features using the original key.*

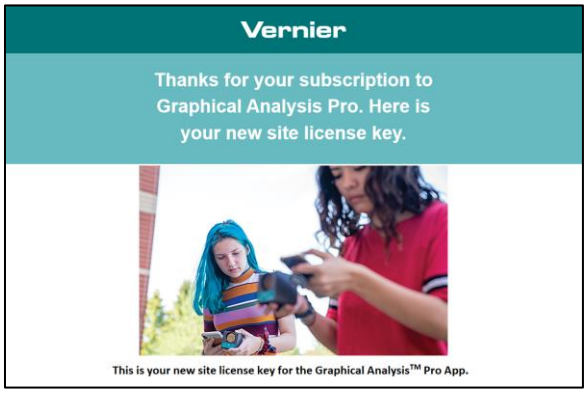


III. Sharing the Graphical Analysis Pro License Key

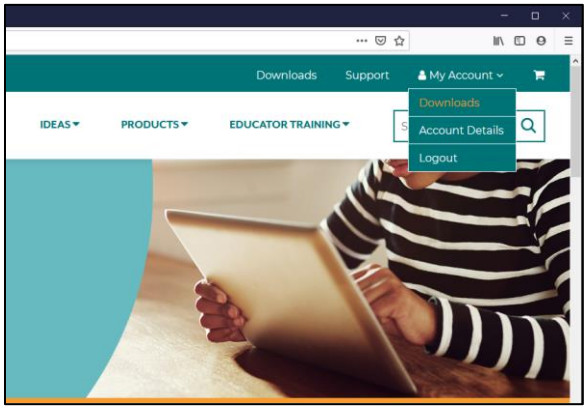
There are several ways in which you can share the Graphical Analysis Pro license key.

- Share the email you received from Vernier that includes the license key with your colleagues.

  The Graphical Analysis Pro license covers all faculty and student devices in a K–12 school or college department.

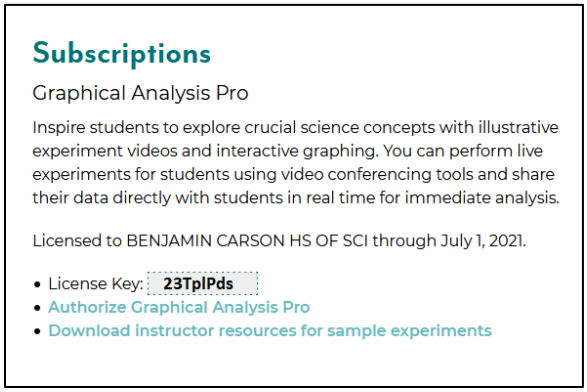


- Access the license key from the Vernier web account of the license owner. The license owner is the person that purchased the software and received the original email from Vernier.



- Email the key to your students or post it on a secure website that only your students and colleagues can access.

  TIP! *Copy the Authorize Graphical Analysis Pro link and share that link with your students that already have Graphical Analysis installed on their devices. Opening the link opens Graphical Analysis with the Pro features already unlocked.*

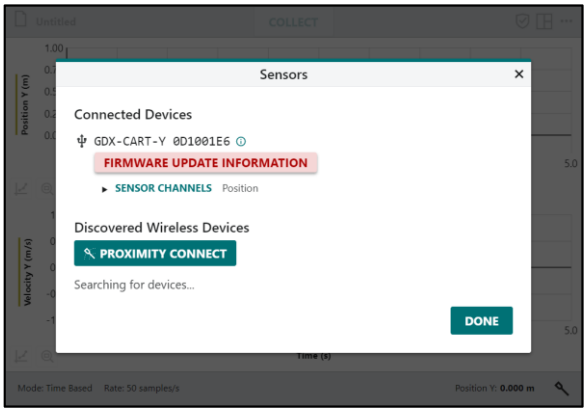


IV. Updating the Firmware on a Go Direct Sensor

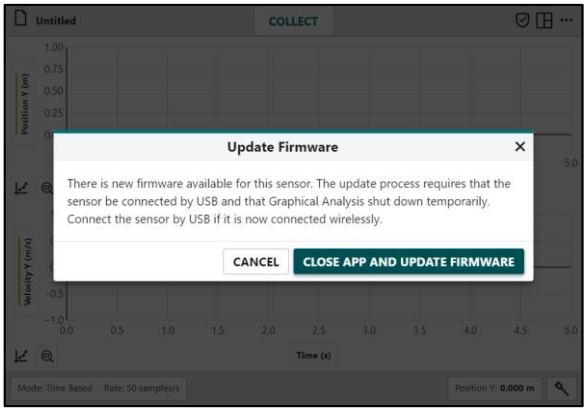
Graphical Analysis automatically checks the firmware version of a sensor when the sensor is connected.

Sensors that have an available firmware update are indicted by the following button FIRMWARE UPDATE INFORMATION.

A firmware update can only be applied when the sensor is connected to a computer or Chromebook via USB. The firmware cannot be updated via a wireless connection.

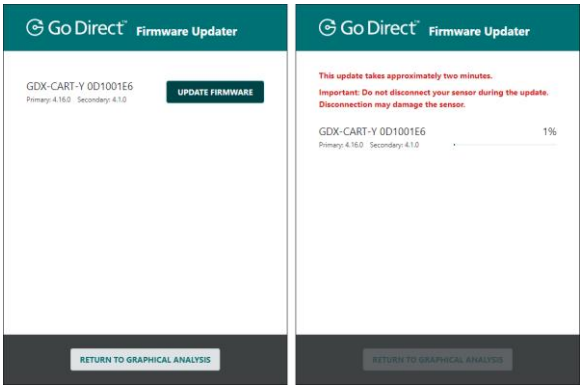


Click or tap **FIRMWARE UPDATE INFORMATION** to start the firmware update for that sensor.



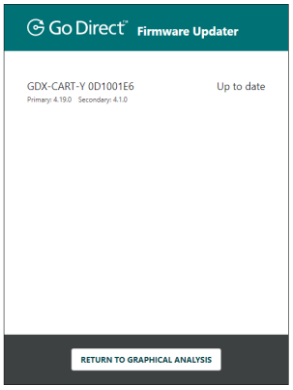
Because Graphical Analysis cannot be running while a sensor is updating, click or tap **CLOSE APP AND UPDATE FIRMWARE** to continue with the Go Direct Firmware Updater application.

Click or tap **UPDATE FIRMWARE** to update the sensor.

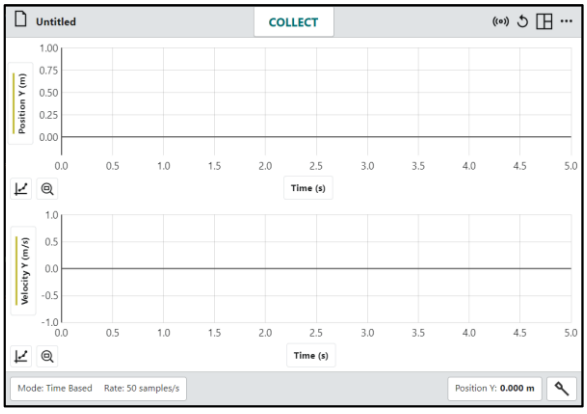


Firmware updates take about two minutes to complete. Progress is indicated via a progress meter next to each sensor being updated.

Once the firmware update is complete, the updated firmware version is shown in the box.



Once all sensors are updated, click or tap **RETURN TO GRAPHICAL ANALYSIS**, and continue with your experiment.



V. Getting Additional Help

Accessing the User Manual

Click or tap Other Options, ⋯, from the top toolbar and choose User Manual to access the user manual as well as online video tutorials for some Graphical Analysis features. This option requires your device to have a live internet connection.

For access to other user manuals, our Technology Information Library, and chat, visit our website:

www.vernier.com/support

You may also contact Vernier directly by phone or email:

Toll Free: 888.837.6437
Email: support@vernier.com

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