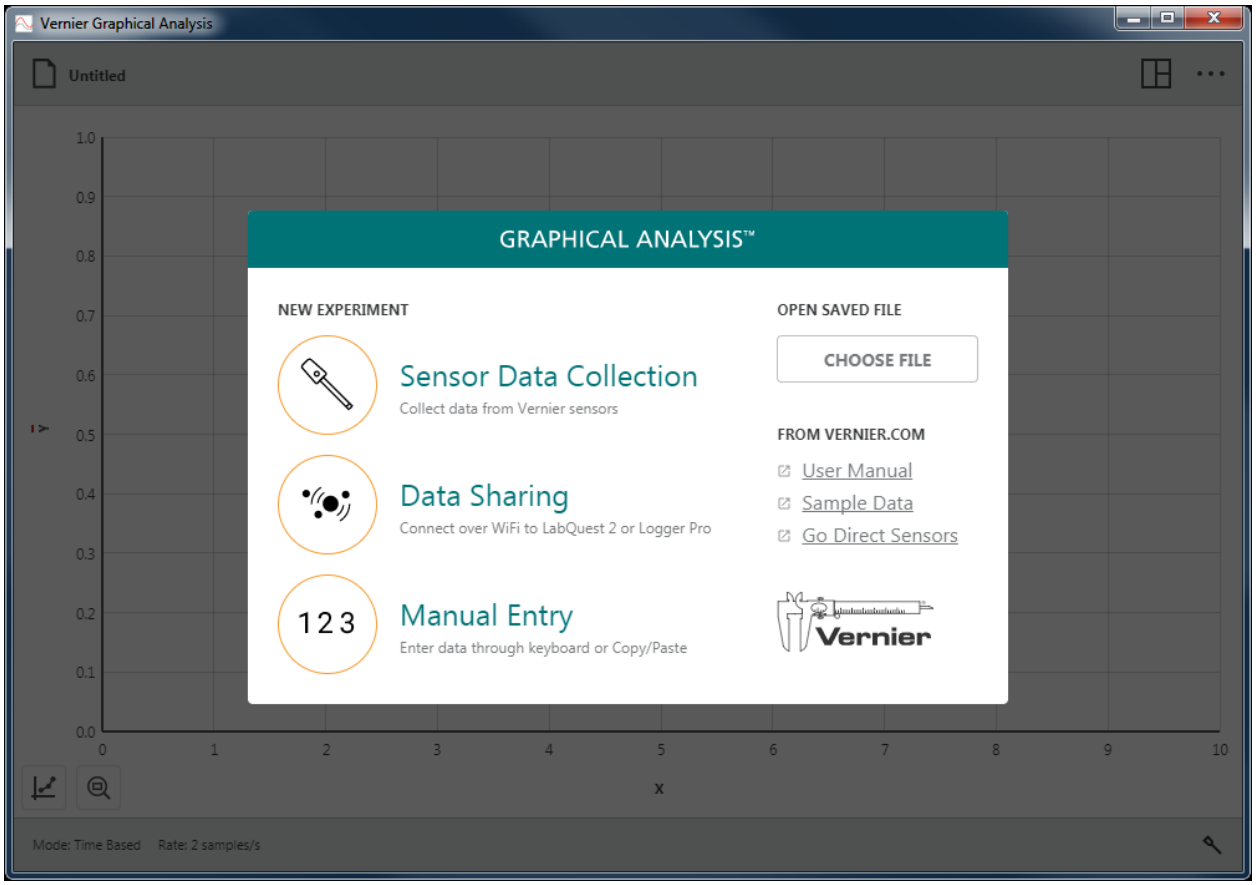
Graphical Analysis™ 4 – User Manual



Version 4.8
March 2019

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ABOUT THIS GUIDE

The Graphical Analysis 4 User Manual is an extended guide detailing the features of the Graphical Analysis 4 app. This guide can be used with any platform-specific version including the versions for Windows® and macOS® computers, Chromebook™ notebooks, and iOS and Android™ devices.

This document reflects features available in Graphical Analysis version 4.8.

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I. GETTING STARTED WITH GRAPHICAL ANALYSIS 4

Downloading Graphical Analysis 4

Windows® and macOS® Computers

Graphical Analysis 4 for Windows and macOS computers is a free download from the Vernier website.

Chrome™ Computing Devices

Graphical Analysis 4 app for Chromebook™ is a free download from the Chrome Web Store.

iOS Devices

Graphical Analysis 4 app for iPad®, iPhone®, and iPod touch® is a free download from the App Store.

Android™ Devices

Graphical Analysis 4 app for Android tablets and phones is a free download from Google Play.

System Requirements

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

Licensing Information

Graphical Analysis 4 is free and can be installed on an unlimited number of computers.

Graphical Analysis 4 apps for Chrome, iOS, and Android are free and distributed through their respective web stores. Terms and licensing are thus determined entirely by these stores.

Privacy Statement

COPPA, SOPIPA, and FERPA Compliance

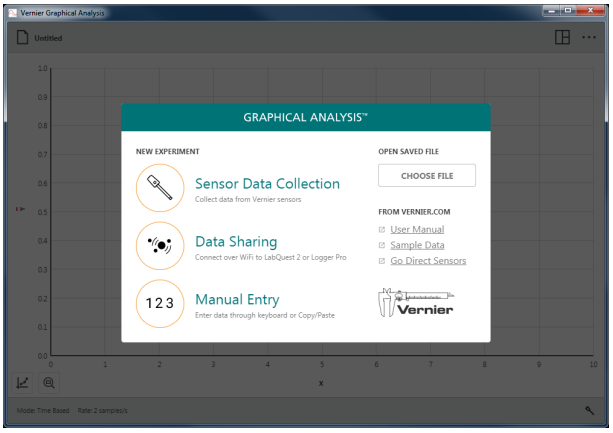
Graphical Analysis complies with federal regulations pertaining to student privacy and safety in the following ways:

- Graphical Analysis does not collect, request, share, or store any personal information from students or teachers.
- Graphical Analysis does not display advertisements in the app.

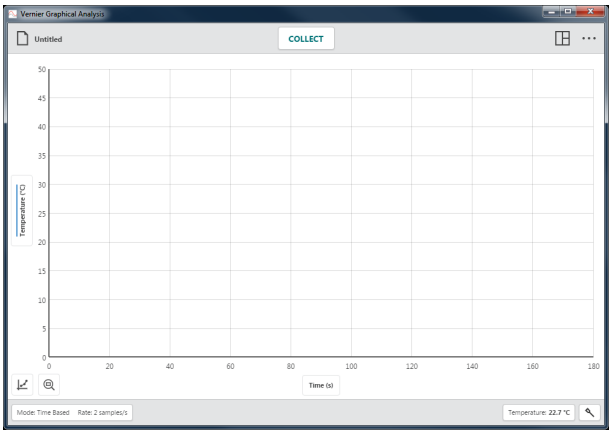
II. QUICK START TO DATA COLLECTION AND ANALYSIS

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

1. Launch Graphical Analysis app.

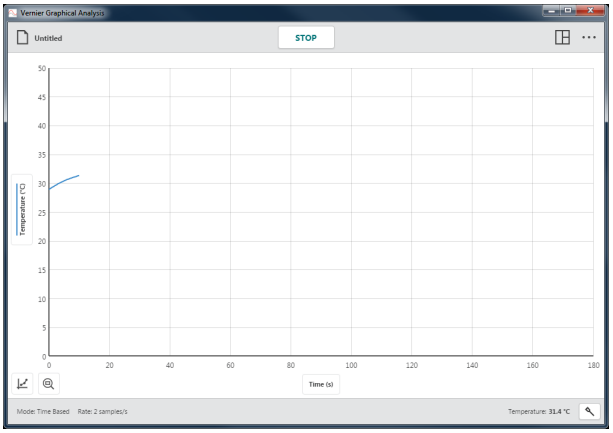


2. Select Sensor Data Collection and connect a sensor. The default collection rate for the sensor is automatically set.



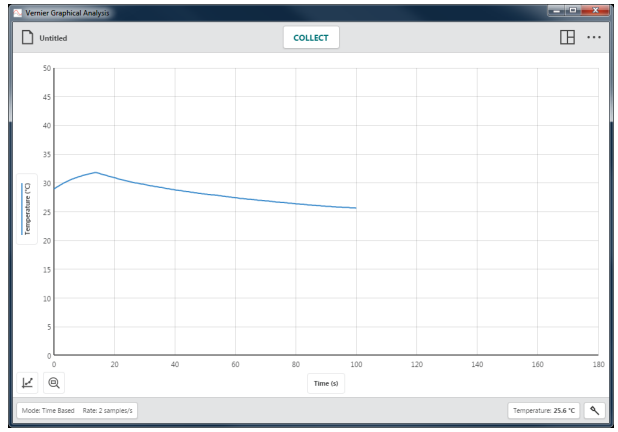
3. Click or tap COLLECT.

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



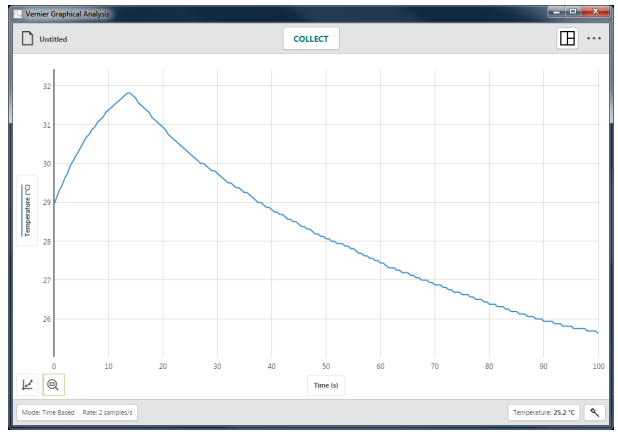
4. Click or tap STOP to manually stop data collection.

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



5. Click or tap to autoscale the graph to fit the data.

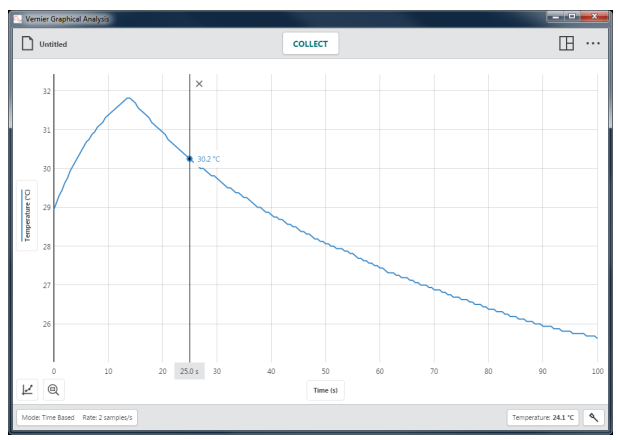
   TIP! *You can also double-click or double-tap the graph to autoscale the graph to fit the data.*



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.

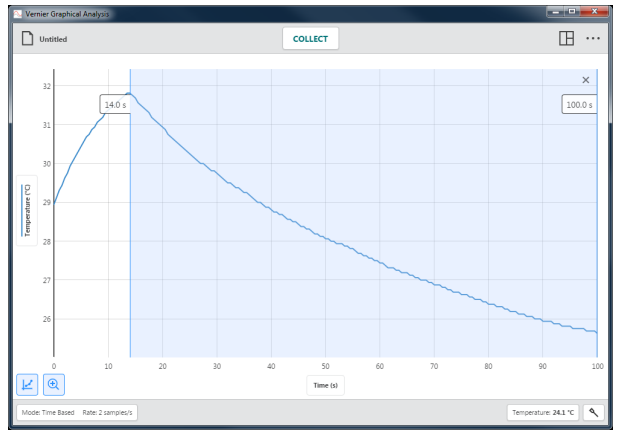
   To remove the examine line, click or tap the close button, ×, displayed next to the line.



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

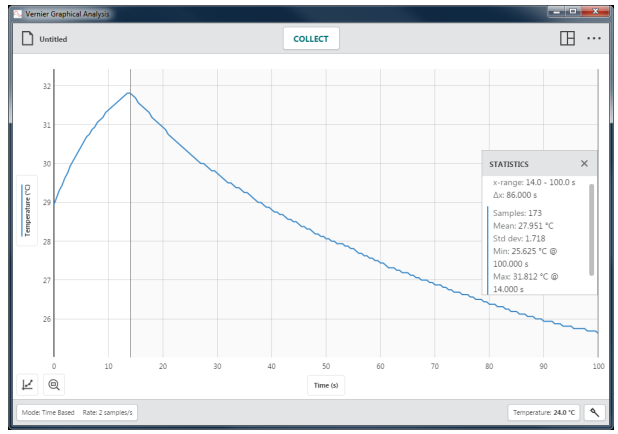
   To modify a region, drag the edges of the region. To remove a selection, click or tap the close button, ×, displayed on the region.

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



8. To view statistics, choose View Statistics from the Graph Tools menu, . The statistics information is displayed on the graph.

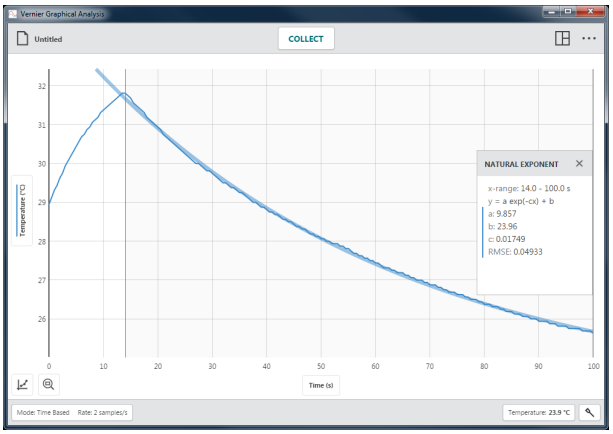
   To remove the displayed statistics, click or tap the close button, ×, on the details box.



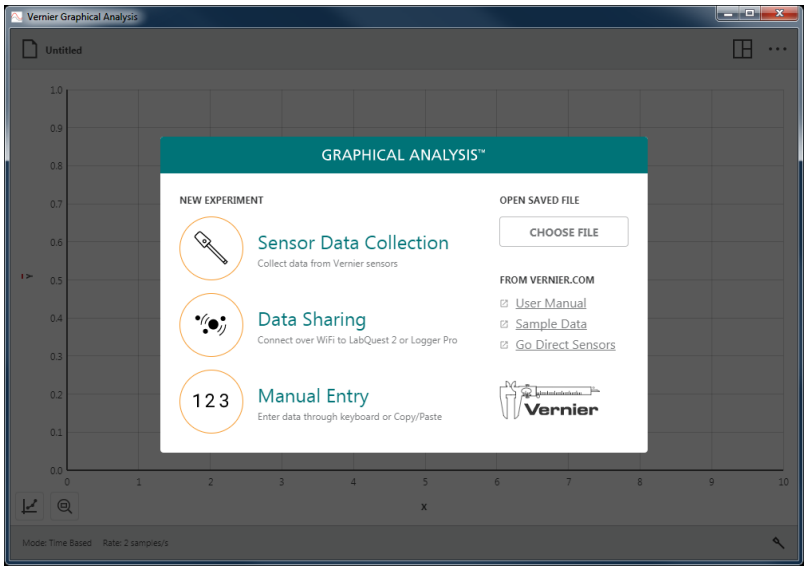
9. To fit a curve to the data, choose Apply Curve Fit from the Graph Tools menu, , then select the desired fit equation. A preview of the curve fit is displayed on the graph.

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

    To remove the curve fit, click or tap the close button, ×, on the details box.



III. NEW EXPERIMENT



When Graphical Analysis 4 is launched without any sensors connected, the New Experiment dialog displays. Choose which type of experiment you want to do within this dialog— Sensor Data Collection, Data Sharing, or Manual Entry. You can also use this dialog to open a saved experiment, access online tutorials, or view sample data.

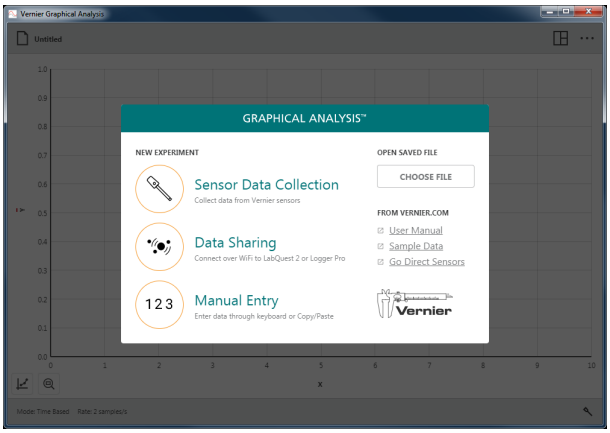
You can access this dialog from any view by clicking or tapping Untitled and choosing New Experiment.

TIP! *If a sensor is connected via USB when Graphical Analysis 4 is launched,* Sensor Data Collection *is automatically selected and this dialog does not display.*

Sensor Data Collection –

1. Launch Graphical Analysis 4.

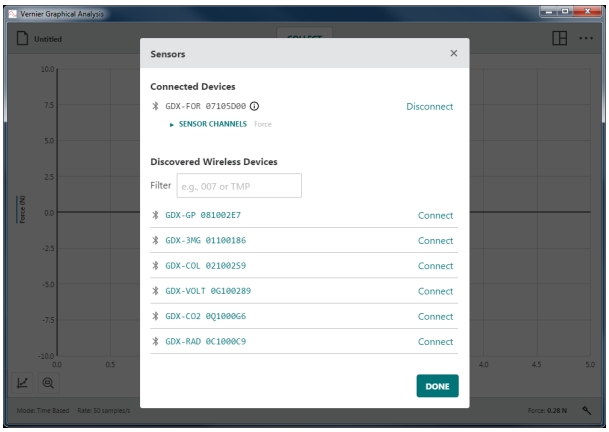
   Click or tap Sensor Data Collection to collect data from sensors and interfaces connected to your computing device. Supported devices include LabQuest® interfaces (LabQuest 2, LabQuest Stream®, LabQuest Mini, Go!Link®), Go Direct® sensors (via USB or Bluetooth® wireless technology), Go!Temp®, and Go! Motion®.



2. Connect your desired sensor(s) or interface.

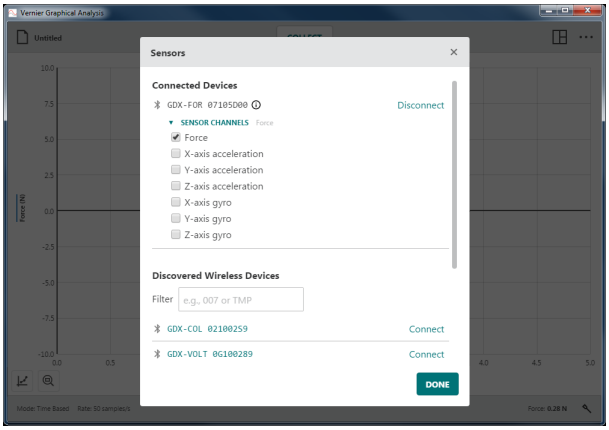
   To connect a wireless sensor, select your desired sensor from the list of discovered wireless devices. The list can be scrolled if needed.

   TIP! *For instructions on connecting to LabQuest Stream® via wireless Bluetooth® wireless technology, see* www.vernier.com/til/4273



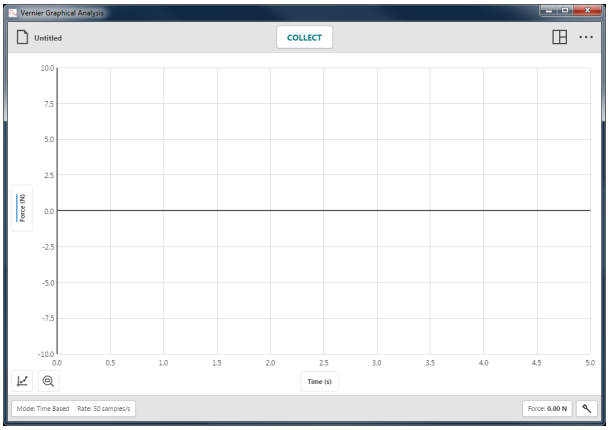
3. When using Go Direct® sensors that have multiple sensor channels, click or tap SENSOR CHANNELS to modify the default sensor configuration for that sensor.

   TIP! *While not explicitly prevented, we do not recommend simultaneously collecting data using different sensor types (LabQuest®, Go Direct, or Go!® sensors).*



4. Click or tap DONE to continue with your experiment.

   TIP! *Click or tap* *to return to the Sensors dialog, where you can add or remove wireless sensors and modify the sensor channel configuration of a connected sensor.*



Data Sharing –

As part of the Connected Science System®, Graphical Analysis 4 can receive wirelessly streamed sensor data from a Data Sharing source such as LabQuest 2 or a computer running our Logger *Pro*® 3 software.

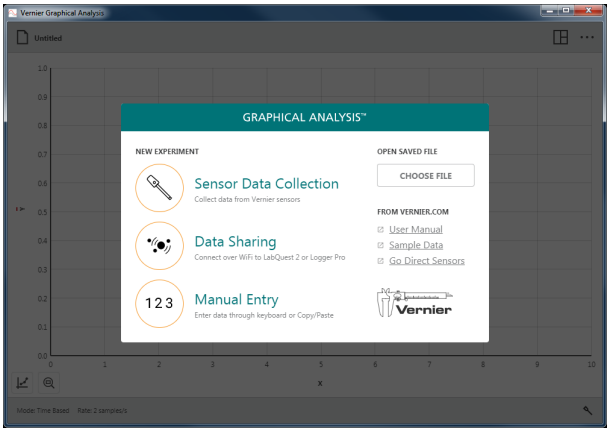
How Data Sharing Works

- Students in a lab group set up an experiment with Vernier sensors and LabQuest 2 or Logger *Pro* 3 software.
- Students use Graphical Analysis 4 to wirelessly connect to the Data Sharing Source using Wi-Fi. ***TIP!*** *Multiple students can simultaneously connect to the same Data Sharing Source.*
- Experiment data is streamed from the Data Sharing source to each student's Graphical Analysis 4 app.
- Each student performs an individual analysis of the data using Graphical Analysis 4.
- If necessary, students can take their data home for further analysis and lab reports.

Connect Graphical Analysis 4 to a Data Sharing Source

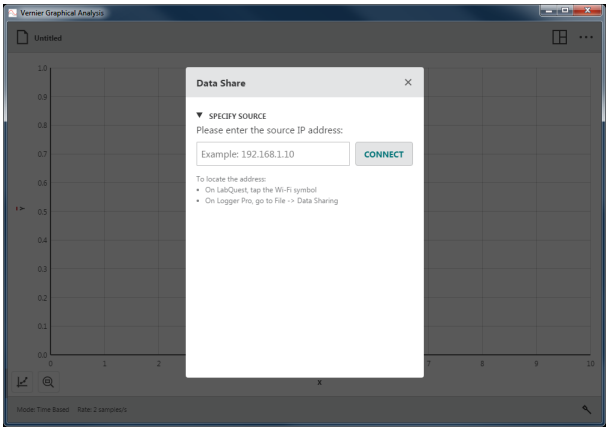
1. Connect your computer, Chromebook™, or mobile device to the same Wi-Fi network used for the Data Sharing source (LabQuest 2 or a computer running Logger *Pro* 3).

2. Launch Graphical Analysis 4.



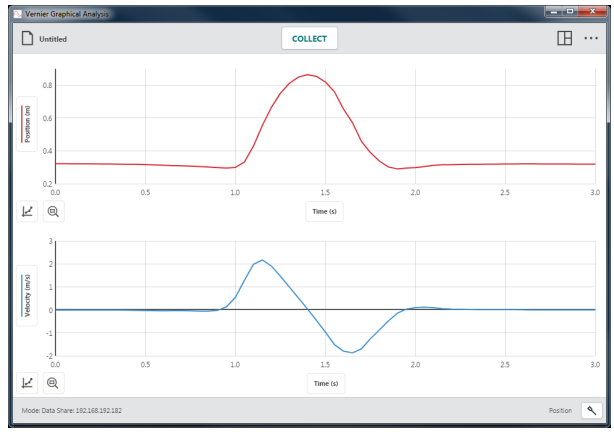
3. Click or tap Data Sharing. Discovered Data Sharing Sources will be listed automatically.

   TIP! *If your device is not listed, you can connect it by choosing* SPECIFY SOURCE *and manually entering the data sharing source IP address.*



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.

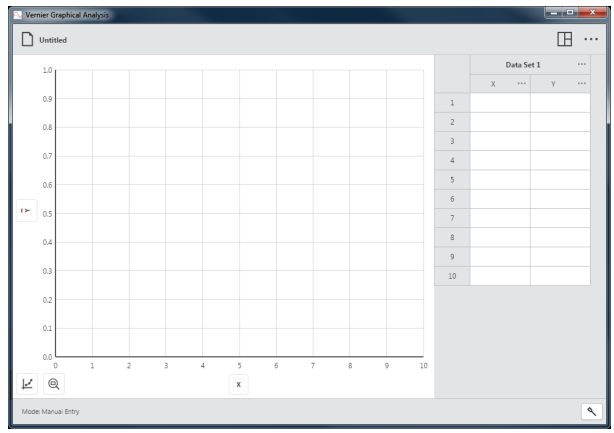
   TIP! *Bottom toolbar buttons are not active during a Data Sharing activity. Data collection and sensor settings are modified on the Data Sharing source (LabQuest® 2 or Logger* Pro® *3 software).*



Manual Entry – 123

Click or tap 123 Manual Entry to initiate an experiment where you manually enter data into a data table. You can use Graphical Analysis 4 to analyze data you collect without sensors as well as data found in textbooks or on the internet.

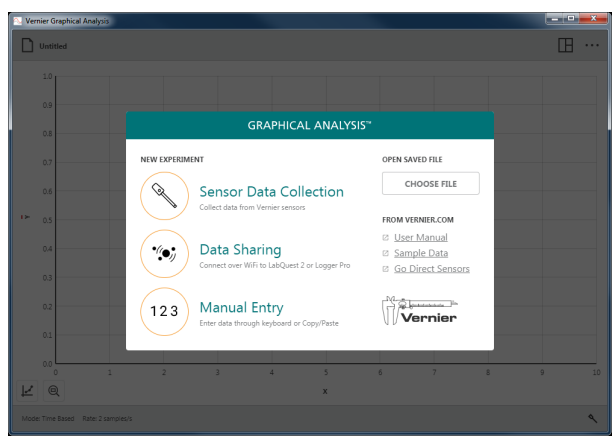
TIP! *Edit tools such as* Cut, Copy, *and* Paste *and our* Add New Data Set *option can make data entry and organization easier in a manual experiment.*



Other Options

OPEN SAVED FILES

Click or Tap CHOOSE FILE to display the Open file dialog for your device. From here, you can access files stored on your device, from an accessible cloud storage location such as Google Drive™ or Dropbox, or from a connected storage device such as a USB drive or SD card (if applicable). You can choose to open a previously saved Graphical Analysis 4 (*.ambl*) file or comma separated value (*.csv*) file.



FROM VERNIER.COM

These options require your device to have an active internet connection.

User Manual

Choose User Manual to launch the default browser with online access to the Graphical Analysis 4 User Manual as well as video tutorials for some of the Graphical Analysis 4 features.

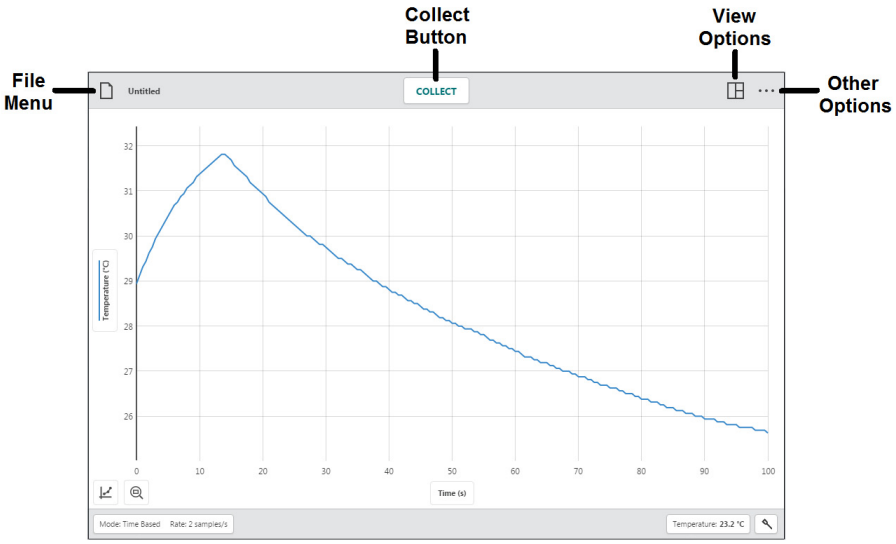
Sample Data

Choose Sample Data to launch the default browser with online access to sample data files for Graphical Analysis 4. Sample files include data for Boyle's Law, Ball Toss, Plant Transpiration, and Periodic Trends.

Go Direct Sensors

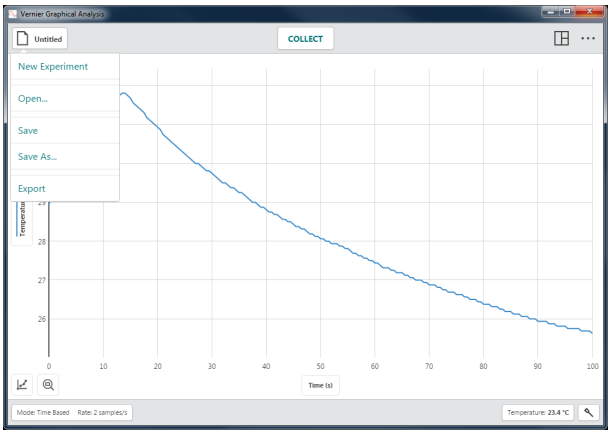
Choose Go Direct Sensors to launch the default browser with online access to information about our Go Direct sensors.

IV. TOOLBAR BUTTONS – TOP BAR



File Menu – Untitled

Click or tap Untitled to access the File menu. From the File menu, you can open, save, and export Graphical Analysis files, along with other tasks.

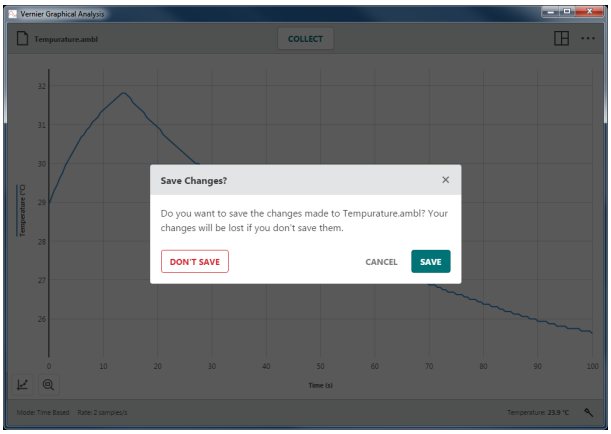


Graphical Analysis 4 files contain data-collection settings, graphs, data tables, and analyses. These files have an *.ambl* extension and can be opened and modified on any device running Graphical Analysis 4.

The data from these files can also be opened using our Logger *Pro*® 3 software.

New Experiment

Choose New Experiment from the File menu 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 *will remain connected when the new experiment is created.*

Open…

Choose Open… from the File menu to display the Open file dialog on your device. From here, you can access files stored on your device, from an accessible cloud storage location such as Google Drive™ 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 4 (*.ambl*) files or comma separated value (*.csv*) files.

Save

Choose Save from the File menu 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…

TIP! *The file menu icon will show the name of the file once the file is saved (e.g.,* Boyles Law.ambl*).*

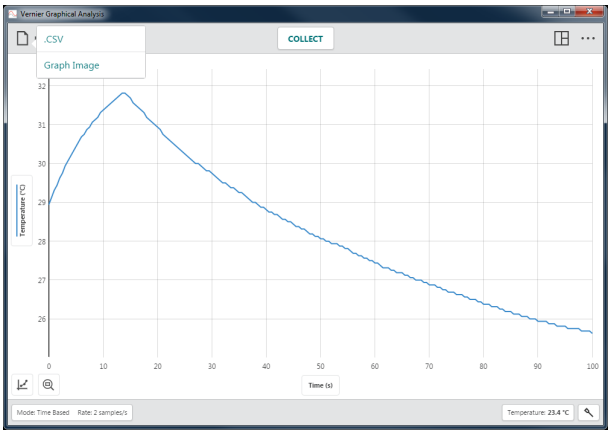
Save As…

Choose Save As… from the File menu to display your devices Save file dialog. From here, 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 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.

Export

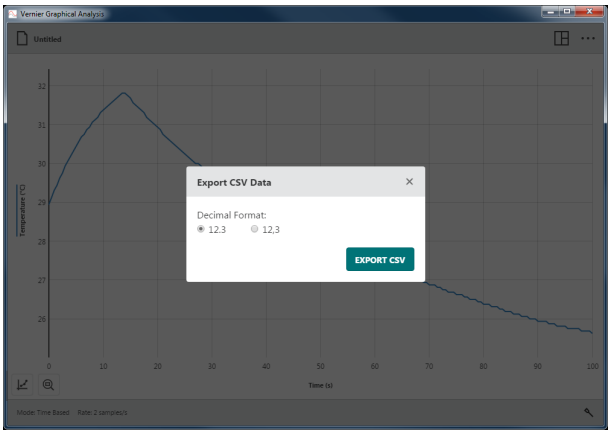
There are two options for exporting a file: .CSV and Graph Image.

- **.CSV**
  Choose Export ▸ .CSV from the File menu to export your experimental data as a .CSV file.



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

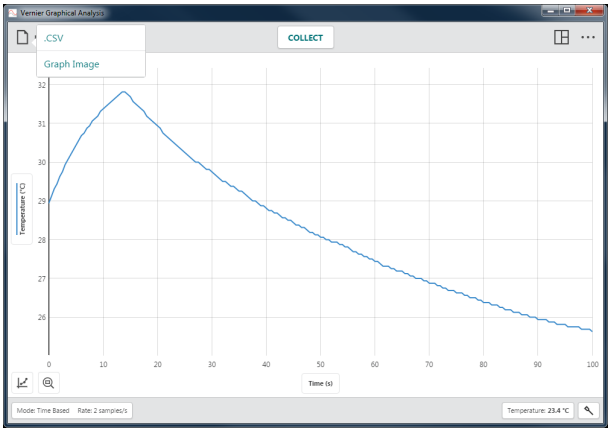
TIP! *Use this feature to save the data in* .csv *format for further analysis with a spreadsheet application or to print your data.*



- **Graph Image**

  Choose Export ▸ Graph Image from the File menu to export an image file (.png) based on your current view of the app.

  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.*



Printing

You cannot print directly from Graphical Analysis 4. 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 4, see* www.vernier.com/til/3789

Collect Button – COLLECT

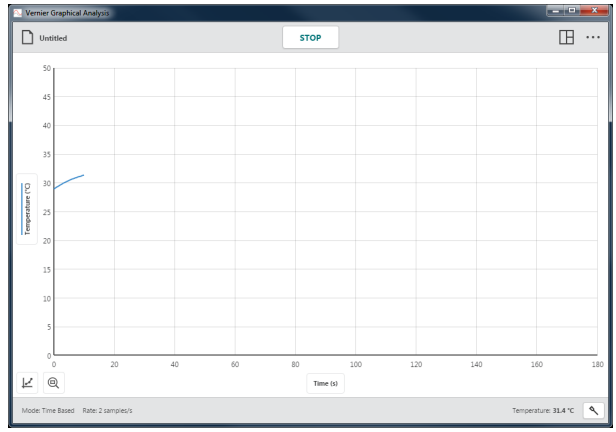
COLLECT is shown when Graphical Analysis is ready to collect sensor data.

Click or Tap COLLECT to start data collection.

While collecting data, some toolbar buttons, such as Mode: Time Based Rate: 2 samples/s and Temperature: 23.7 °C, are no longer accessible.

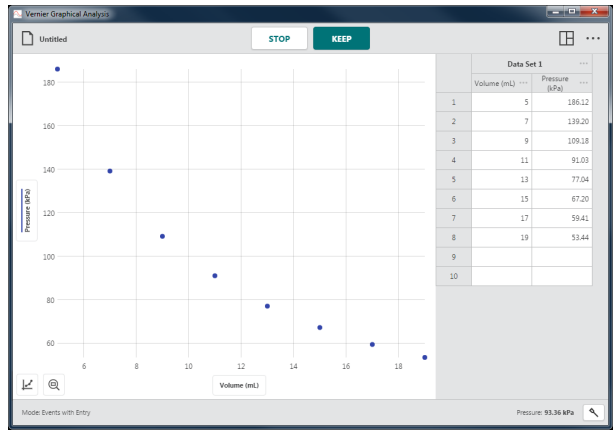
Click or tap STOP to end data collection, or wait until data collection ends automatically.

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



For event-based data collection, the collect button is shown with a KEEP button.

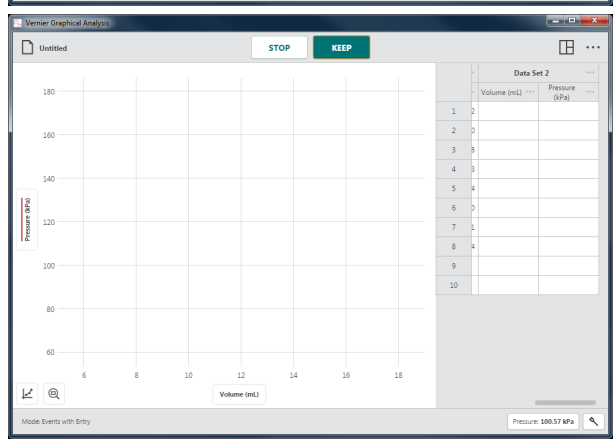
1. Click or tap COLLECT to start data collection.
2. Click or tap KEEP to record a data point; repeat as needed.
3. When finished collecting data, click or tap STOP to end data collection.



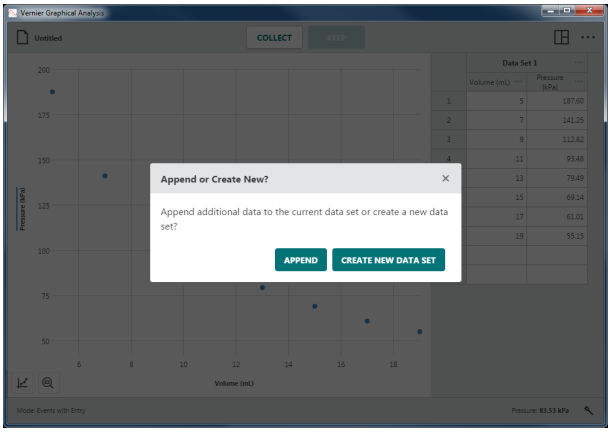
Collecting Multiple Data Sets

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 vertical-axis (y-axis) label and select the desired data set.*



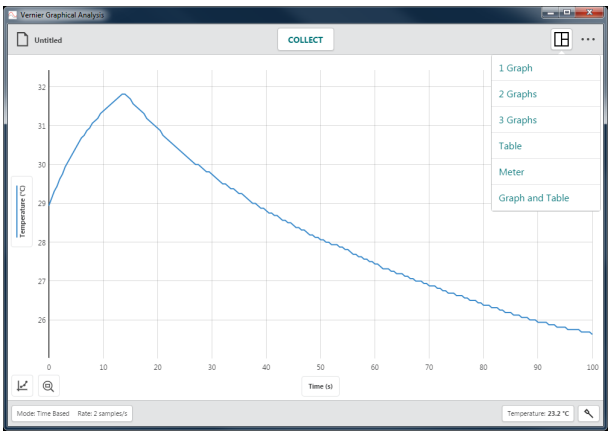
For event-based data collection, you can append new data to your existing data set or start a new data set.



View Options – ⊞

Graphical Analysis automatically displays a view based on the experiment type, data-collection mode, and connected sensors. You can use this recommended view or choose from any of the available views.

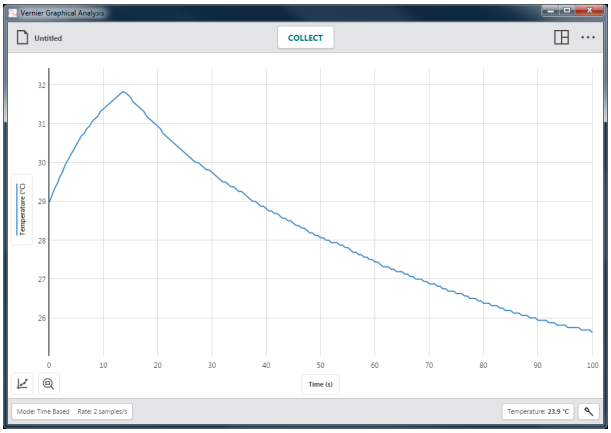
Click or tap ⊞ to select the desired view.



1 Graph

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

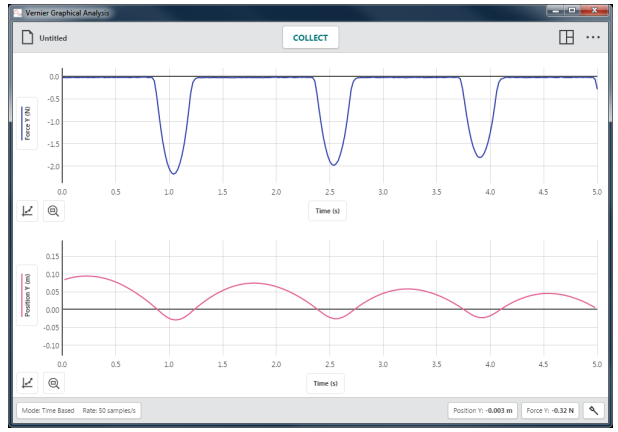
This view is also used when there are multiple sensors all using the same unit of measure.



2 Graphs

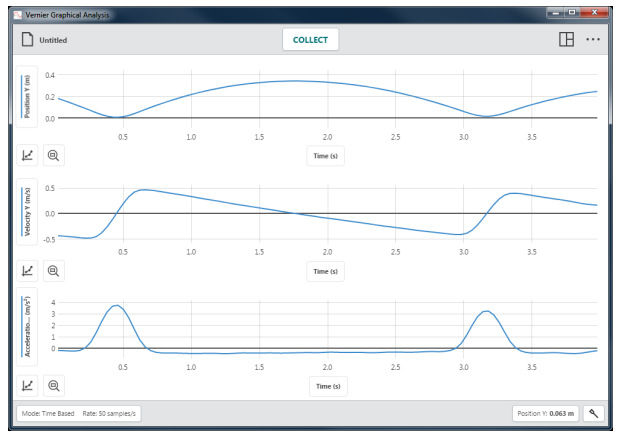
This is the default view of time-based data collection with two (or more) sensors when the sensors have two different units of measure.

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.



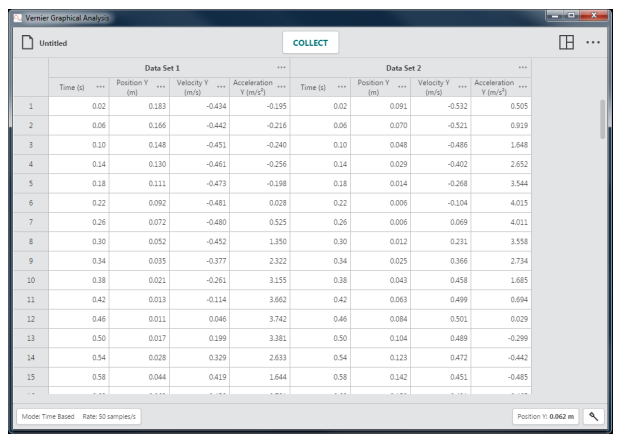
3 Graphs

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

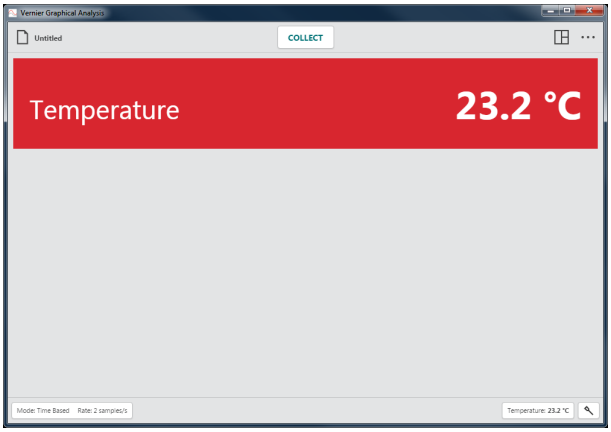
This view shows the data table. While this view is not displayed by default, it is always available.



	Data Set 1				Data Set 2			
	Time (s)	Position Y (m)	Velocity Y (m/s)	Acceleration Y (m/s²)	Time (s)	Position Y (m)	Velocity Y (m/s)	Acceleration Y (m/s²)
1	0.02	0.183	-0.434	-0.195	0.02	0.091	-0.532	0.505
2	0.06	0.166	-0.442	-0.216	0.06	0.070	-0.521	0.919
3	0.10	0.148	-0.451	-0.240	0.10	0.048	-0.486	1.648
4	0.14	0.130	-0.461	-0.256	0.14	0.029	-0.402	2.652
5	0.18	0.111	-0.473	-0.198	0.18	0.014	-0.268	3.544
6	0.22	0.092	-0.481	0.028	0.22	0.006	-0.104	4.015
7	0.26	0.072	-0.480	0.525	0.26	0.006	0.069	4.011
8	0.30	0.052	-0.452	1.350	0.30	0.012	0.231	3.558
9	0.34	0.035	-0.377	2.322	0.34	0.025	0.366	2.734
10	0.38	0.021	-0.261	3.155	0.38	0.043	0.458	1.685
11	0.42	0.013	-0.114	3.662	0.42	0.063	0.499	0.694
12	0.46	0.011	0.046	3.742	0.46	0.084	0.501	0.029
13	0.50	0.017	0.199	3.381	0.50	0.104	0.489	-0.299
14	0.54	0.028	0.329	2.633	0.54	0.123	0.472	-0.442
15	0.58	0.044	0.419	1.644	0.58	0.142	0.451	-0.485

Meter

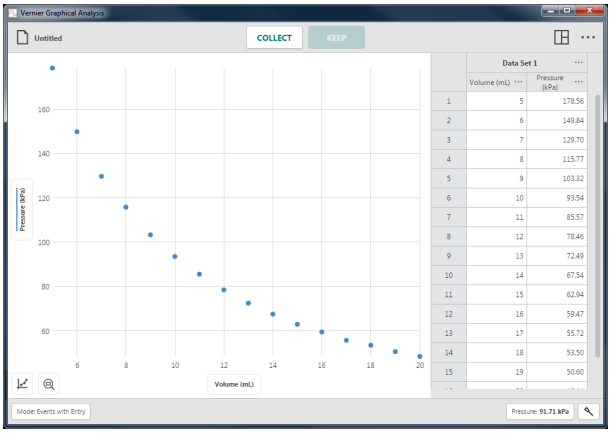
This view shows large meters for the connected sensors. While this view is not displayed by default, it is always available.



Graph and Table

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

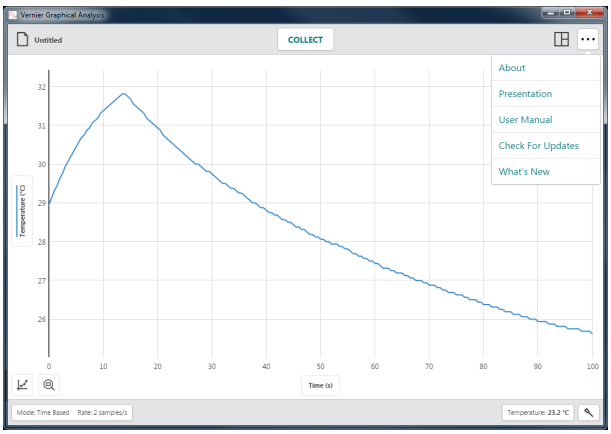
TIP! *The displayed graph utilizes the same graph set up as shown in* 1 Graph *view.*



Other Options – ···

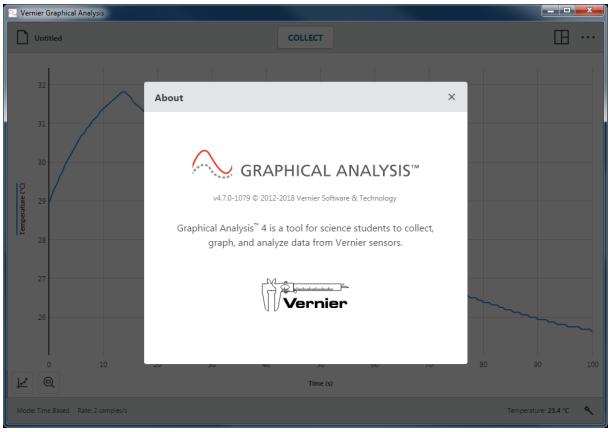
Other options available in Graphical Analysis depend on the device you are using. Not all options are available on every platform.

Click or tap ··· to access the available options for your device.

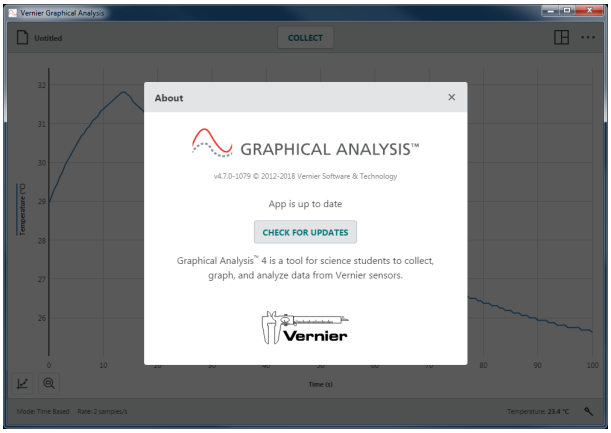


About

Choose About to see what Graphical Analysis version you are running.

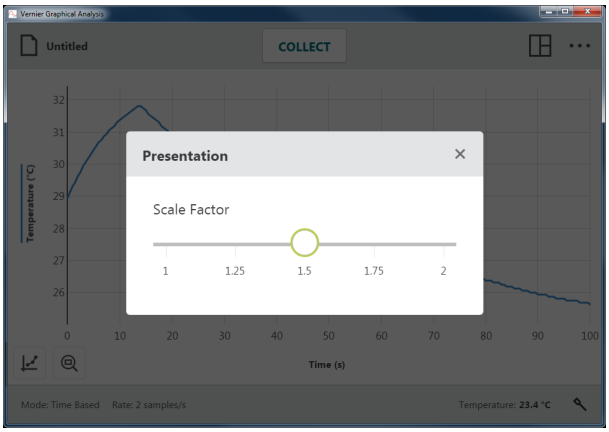


When using computers, the About dialog also provides a way to check for updates.



Presentation

Choose Presentation to modify the font-size scale factor used in Graphical Analysis. This is particularly useful when presenting the app with a projector or viewing the app on a device with a high-resolution screen.



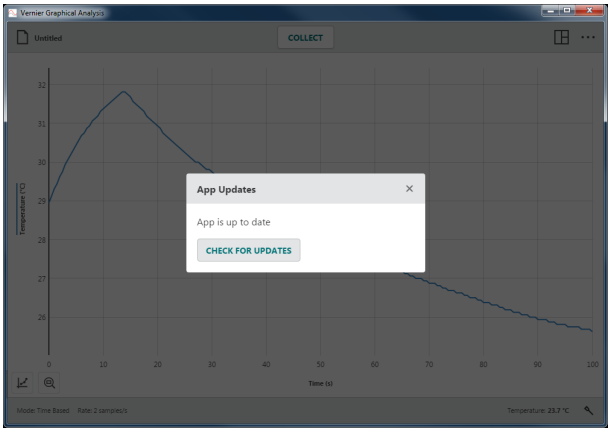
User Manual

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 an active Internet connection.

Check For Updates

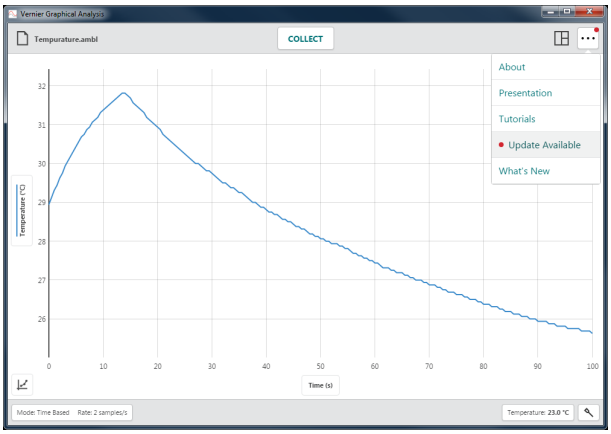
Choose Check For Updates to ensure you are running the latest version of Graphical Analysis. You can choose to update if a newer version is available. This option requires your device to have an active Internet connection.

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

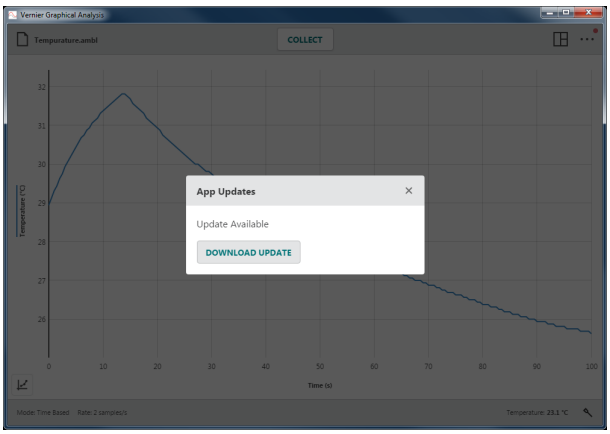


Graphical Analysis automatically checks for updates when your computer has an Internet connection. When a newer version of software is available, the Other Options button on the top toolbar is displayed with a red dot, ⋯.Follow the steps below to update Graphical Analysis.

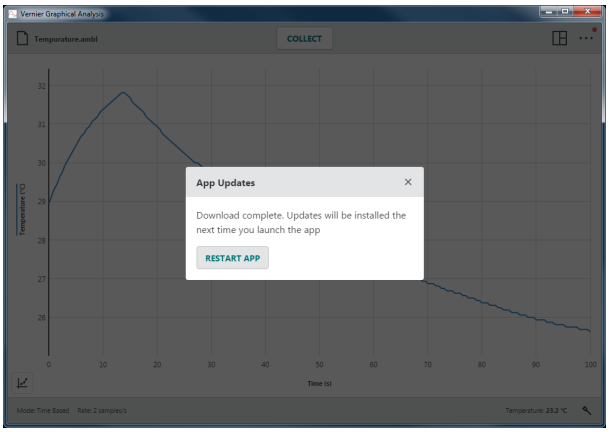
1. Click or tap ⋯ to access the Other Options menu and select ● Update Available.



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



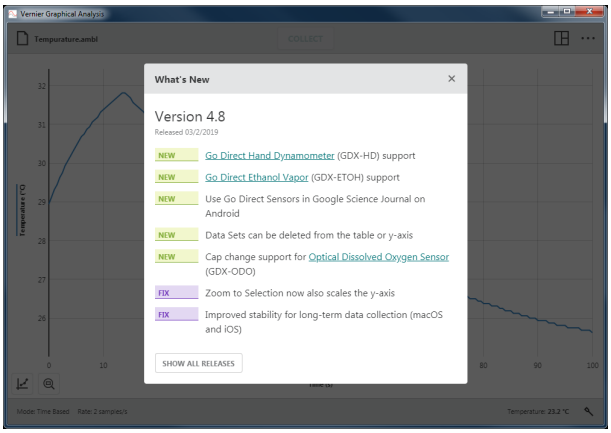
3. The app must restart for the update to install. Click or tap RESTART APP to complete the update.



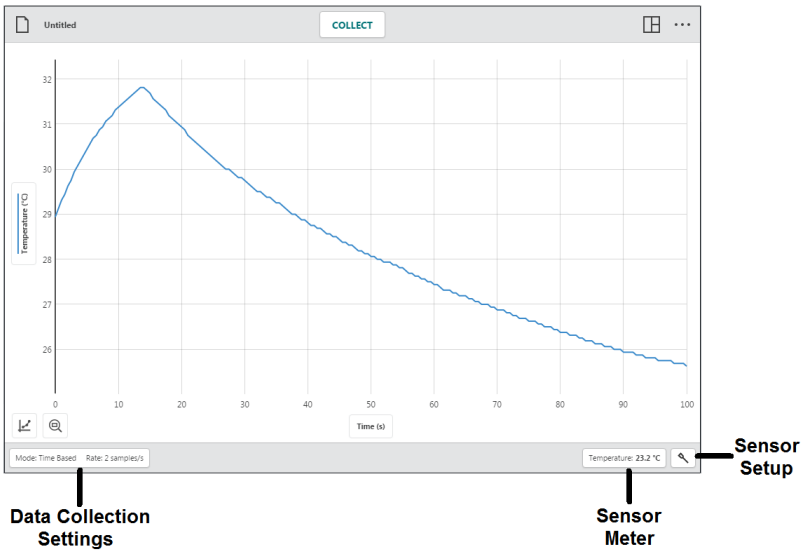
What's New

Choose What's New to view a summary of the new features and fixes available in the most recent version of Graphical Analysis.

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



V. TOOLBAR BUTTONS – BOTTOM BAR



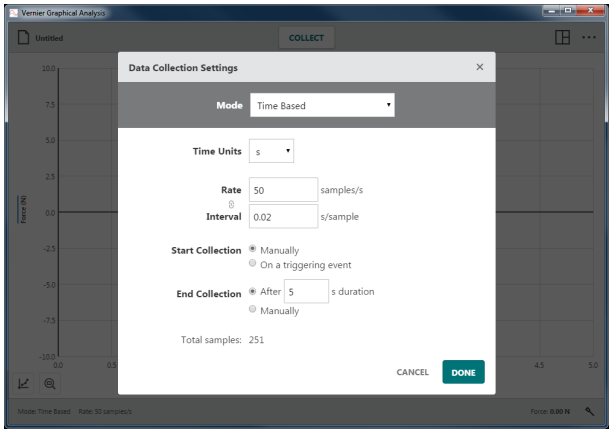
Data-Collection Settings – Mode: Time Based Rate: 50 samples/s

Click or tap Mode: Time Based Rate: 50 samples/s to access the data-collection settings. The parameters listed will 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.

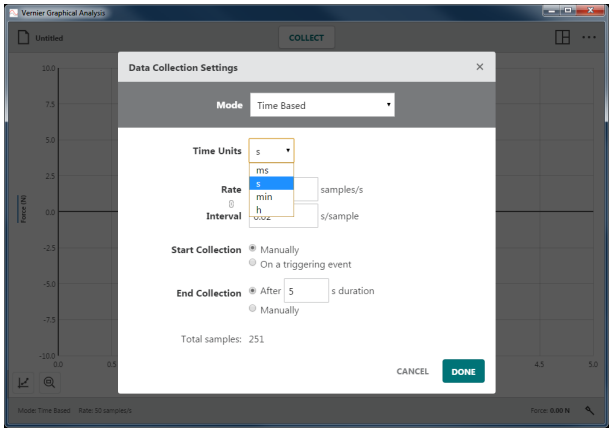
Parameters for this mode include Time Units, Rate and Interval, and Start and End Collection options. The total number of samples to be collected based on these parameters is displayed.



- **Time Units**

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

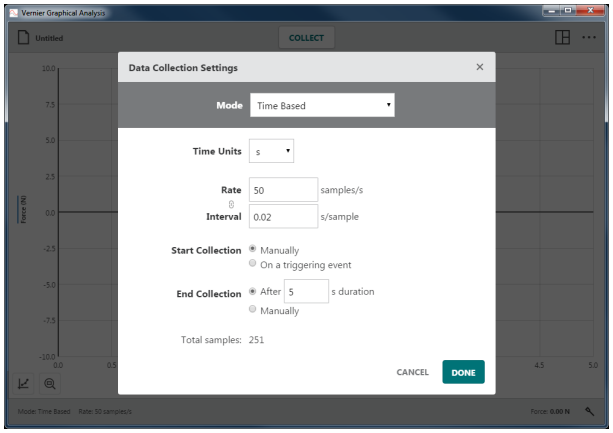
  Time unit changes are applied to the rate, interval, and duration values as indicated by their units.



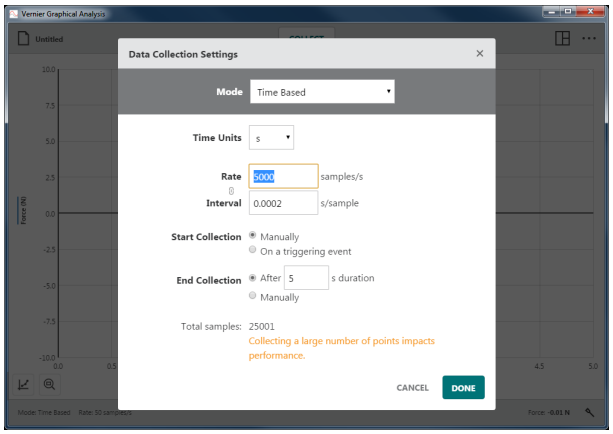
- **Rate** and **Interval**

  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.

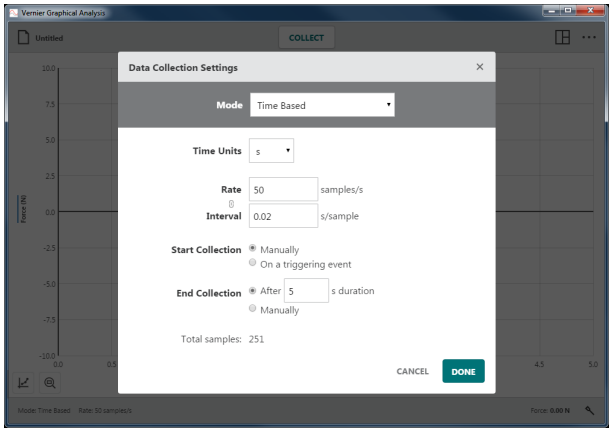


- **Start Collection**

  The two options for starting data collection are Manually and On a triggering event.

  Manually

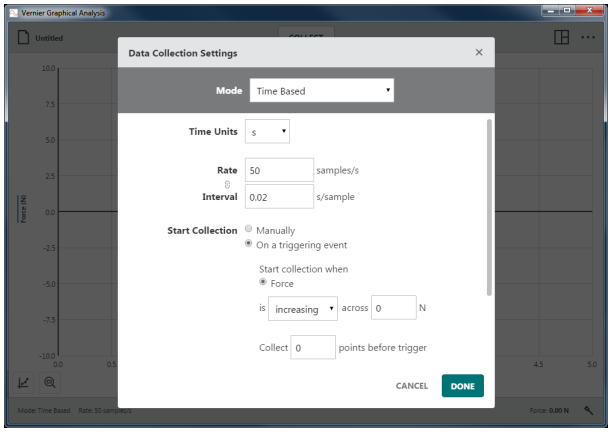
  This is the default option that requires you to click or tap COLLECT to start data collection.



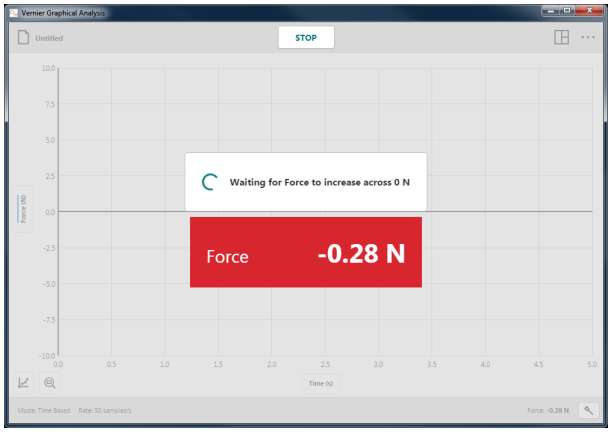
  On a Triggering Event

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

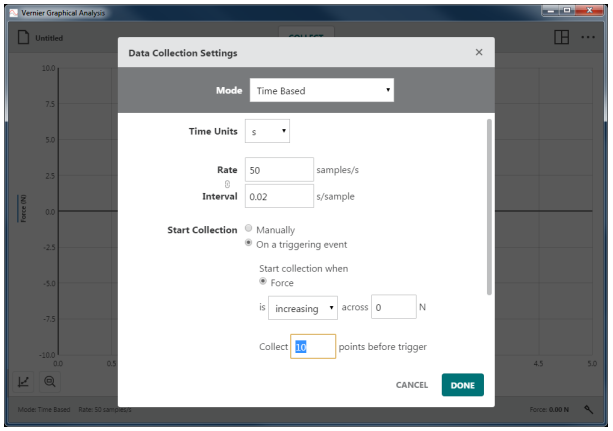
  Choose the sensor used for the trigger and set the trigger threshold value. You can trigger as the sensor reading increases or decreases past the threshold value.



  Click or tap COLLECT to start monitoring for the trigger. When the trigger condition has been met, data will be plotted 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.



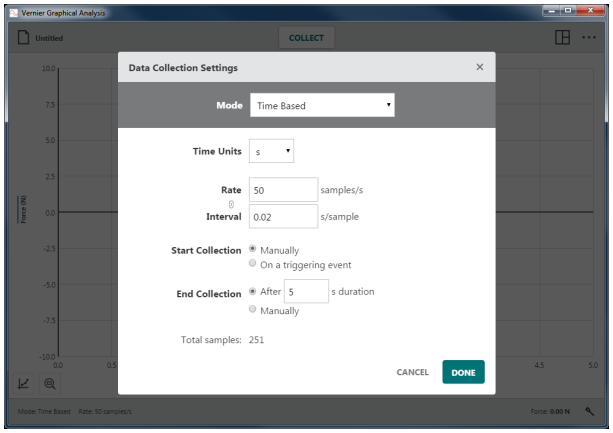
- **End Collection**

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

After Fixed Duration

Ending after a fixed duration is the default option. Data collection will continue until the duration time has been met.

The default Duration is determined by the connected sensor and can be modified. When more than one sensor is connected, the default duration will be the shortest duration of the conneted sensors.



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

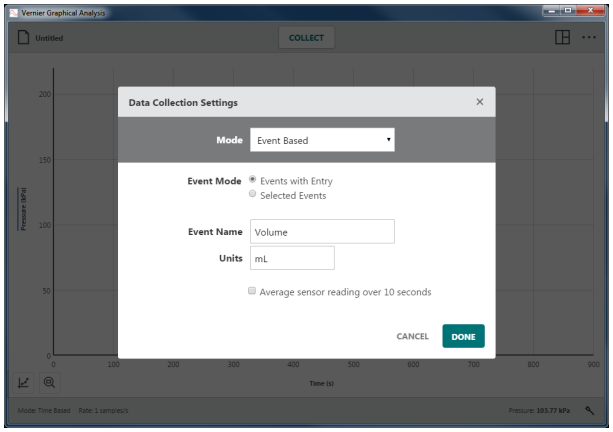
Manually

This option requires you to click or tap STOP to end a 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 gas.

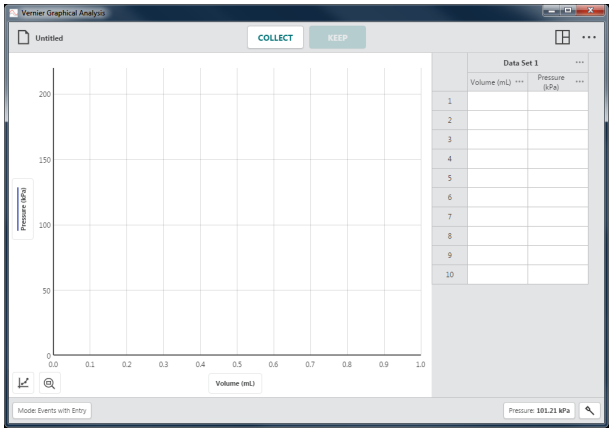
Parameters for this mode include Event Mode and 10-second averaging. You can also provide a name and units for the "Event" column.



The default view for event-based data collection is Graph and 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.*

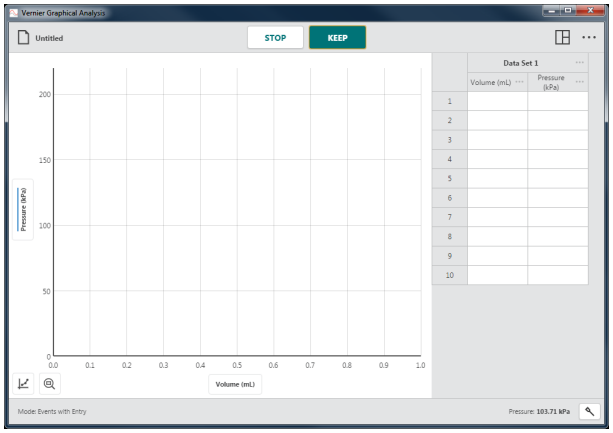


- **Event Mode: Events with Entry**

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

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

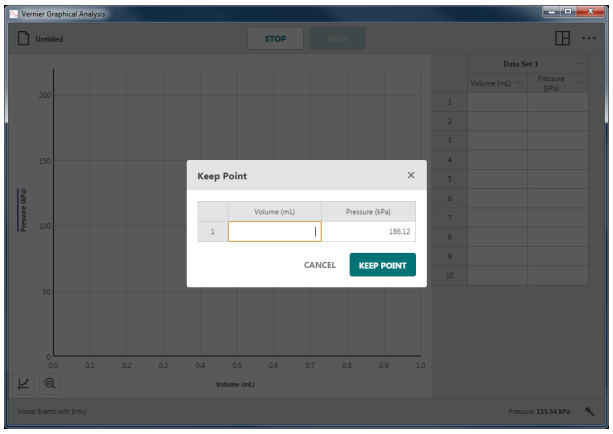
  TIP! *In event-based data collection, sensors are sampled 10 times each second while data collection is active.*



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

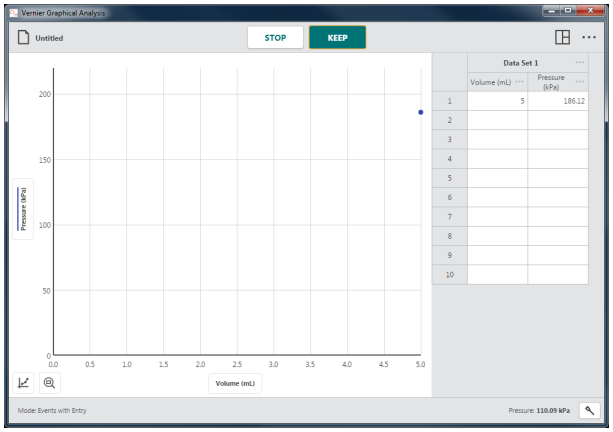
  When Events with Entry is selected, you are prompted for the "Event" value.

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

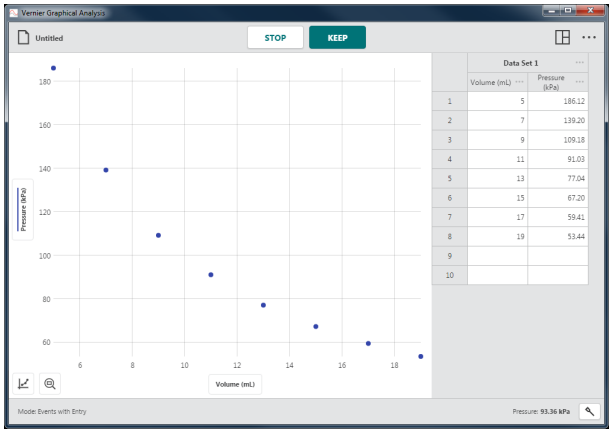
The point is automatically plotted on the graph.



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

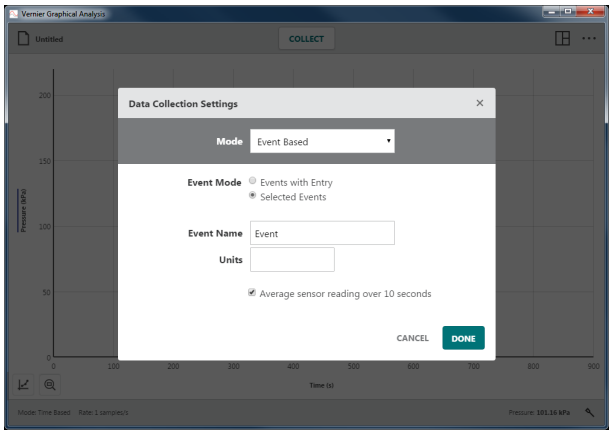
TIP! *The graph rescales automatically as you* KEEP *each point to ensure all data points are shown on the graph.*

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

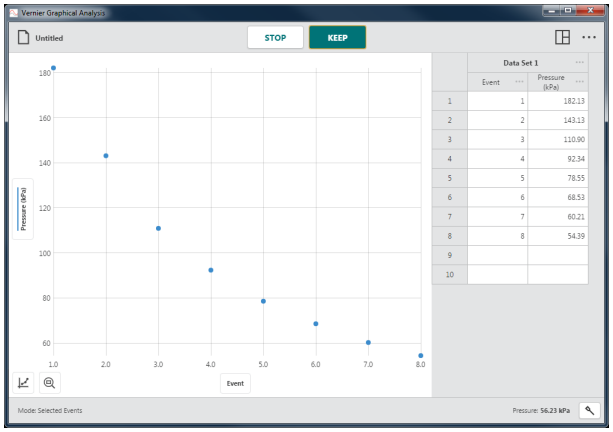


- **Event Mode: Selected Events**

  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.

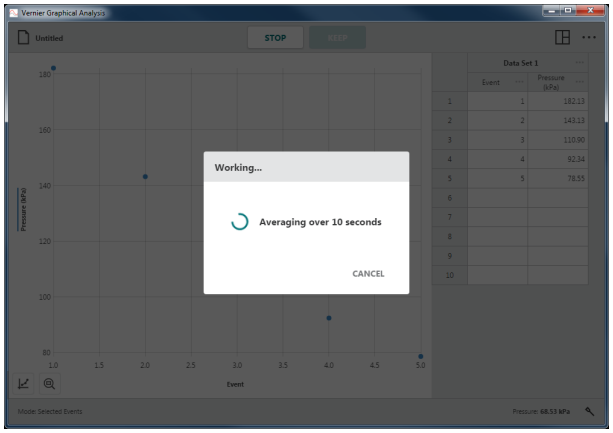


- **Average over 10 seconds**

  This option reports the average sensor reading over a 10-second collection. Click or tap KEEP to initiate a 10-second data collection.

  Sensors are sampled at 10 samples per second.

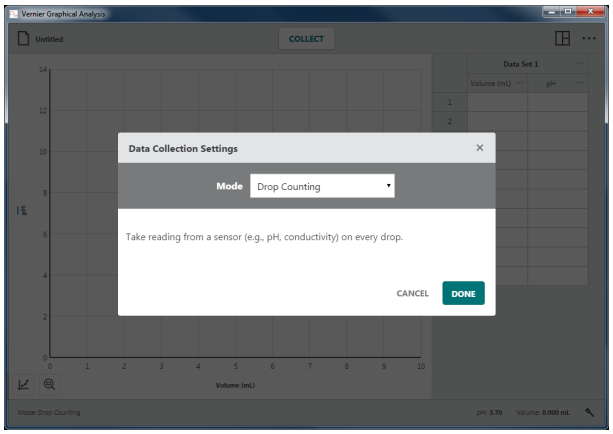
  TIP! Average over 10 seconds *can be used with either Events with Entry or Selected Events event modes.*



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

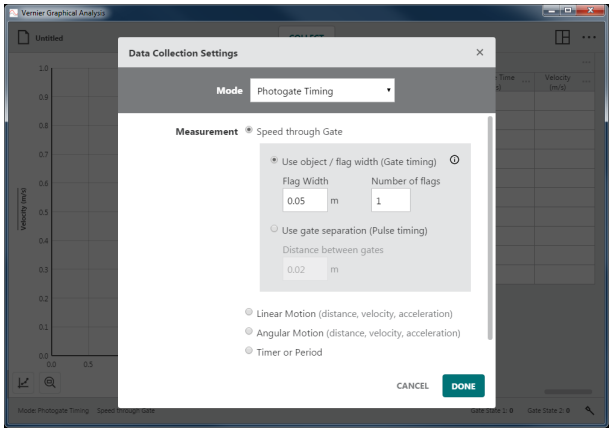
Photogate Timing mode is the default mode whenever a wired (BTD) Photogate or Projectile Launcher is connected. When using this mode, the time a gate is blocked or unblocked is recorded as an object passes through the gate. The times are used to determine attributes of the motion of the object. Which 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

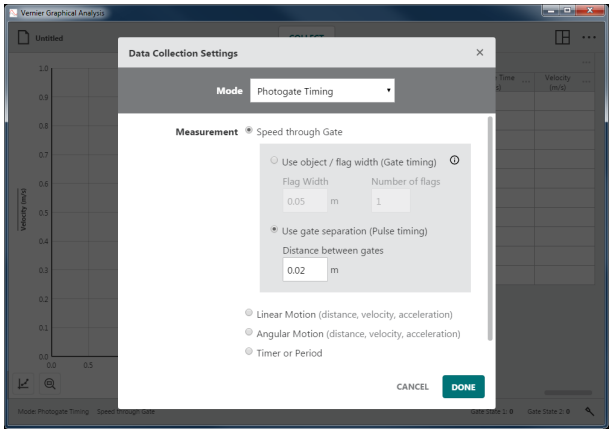
  For a single photogate, the speed of an object passing through the gate is determined by dividing the width of the object that blocks the gate by the time duration the object is blocking the gate.



  Use gate separation

  For 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.

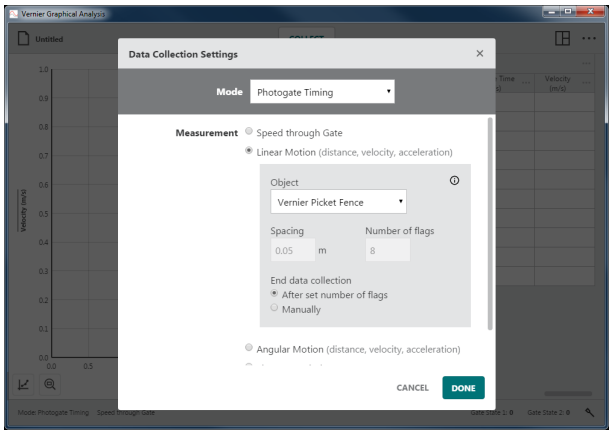
  TIP! *You can find the average speed of an object as it passes between any pair of gates as long as the gate separation is known.*



- **Linear Motion (distance, velocity, acceleration)**

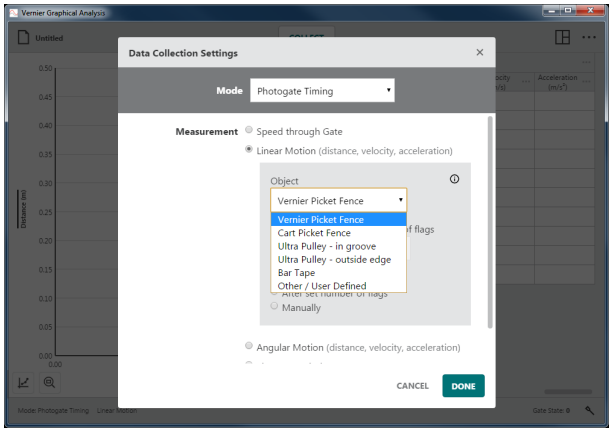
  This is the default photogate option when only one photogate is used.

  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.



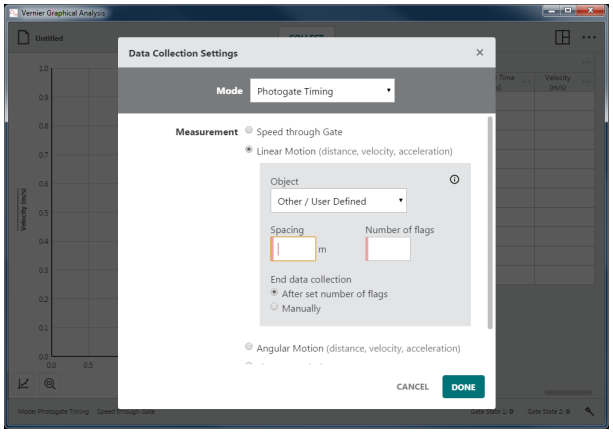
Object

Objects sold by Vernier can be selected from the 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.

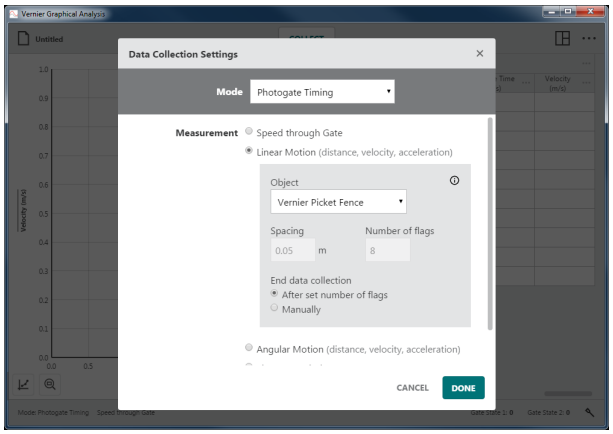
TIP! *If the object is a wheel with multiple spokes,* Spacing *is the circumference of the wheel divided by the number of spokes and* Number of flags *equals the number of spokes.*



End Data Collection

Choose After set number of flags to automatically stop collection after the object has completely passed through all gates.

Choose Manually to continuosly collect data until you click or tap STOP.



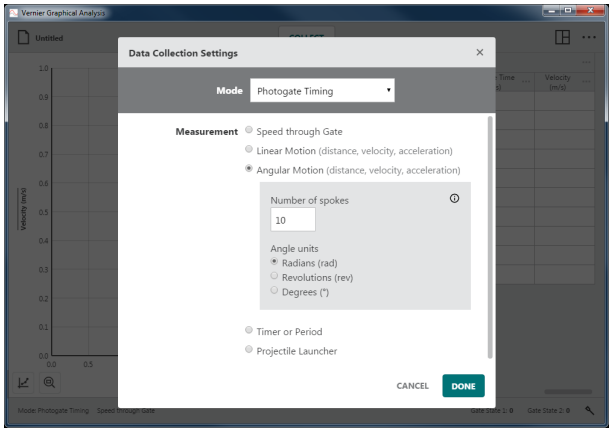
- **Angular Motion (distance, velocity, acceleration)**

  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°*



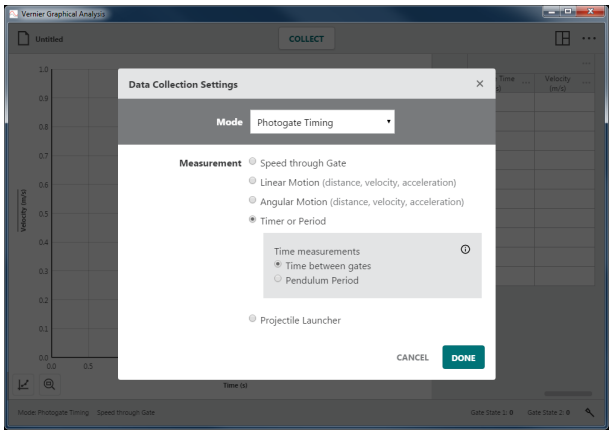
- **Timer or Period**

  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.

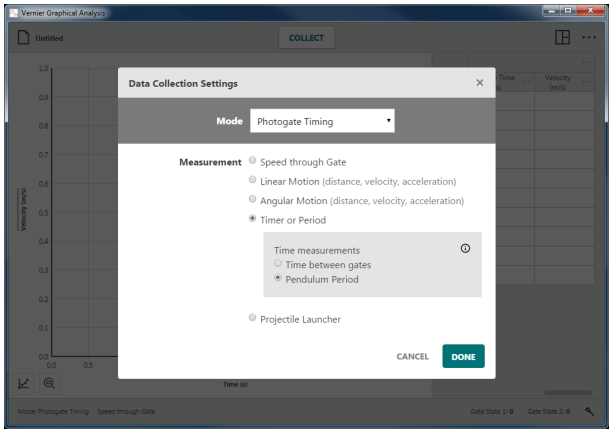
TIP! *You can also use this option to measure times between successive blocks of a single photogate.*



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.*

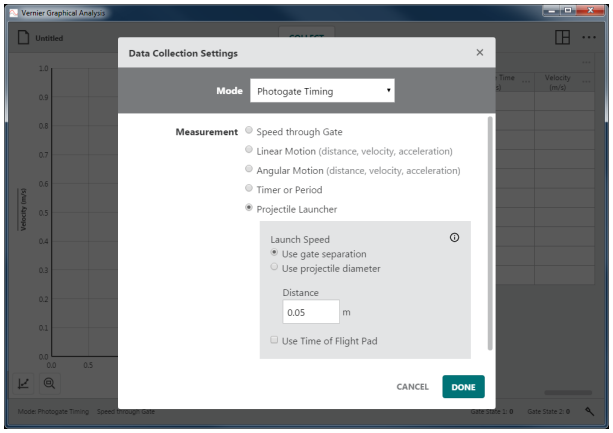


- **Projectile Launcher**

  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

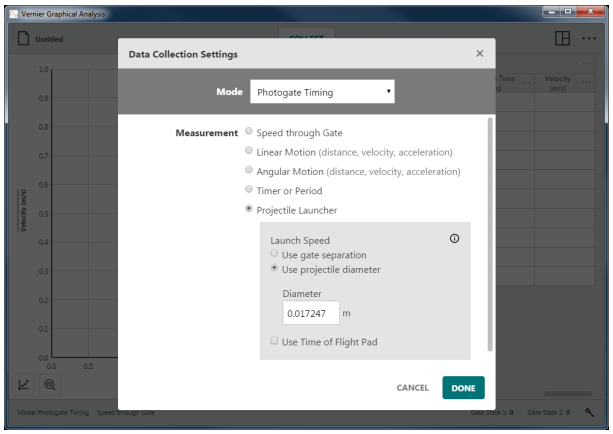
This option uses the distance between the two launch photogates to determine the launch speed of the projectile. The default distance is 0.05 m.



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* [BTD] *photogates with this mode as long as the photogates are daisy-chained together, reporting a single gate-state column in the data table.*

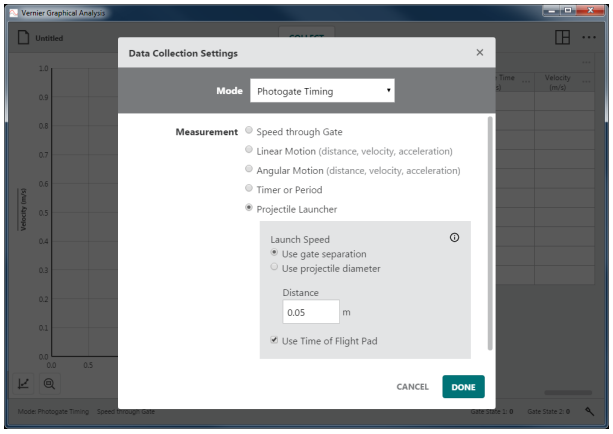


Use Time of Flight Pad

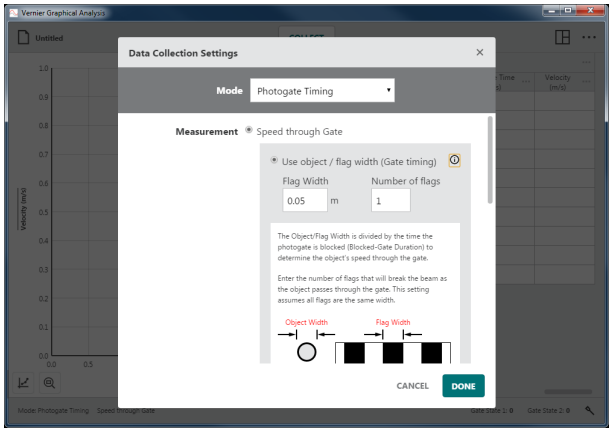
The Time of Flight Pad accessory is required when using this option.

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.*



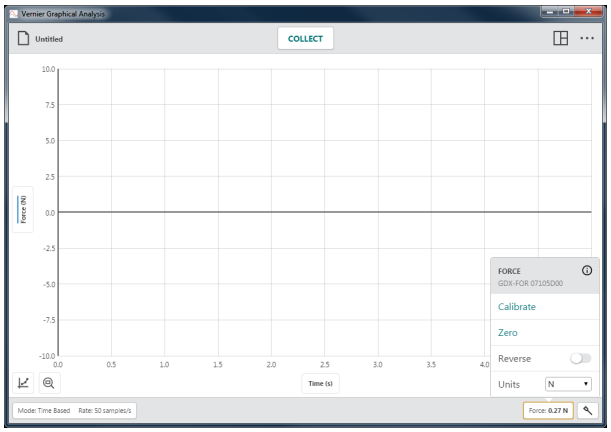
TIP! *You can click or tap ⓘ for Photogate setup information for any of the photogate timing measurements.*



Sensor Meters – Force: 0.25 N

A digital meter 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.

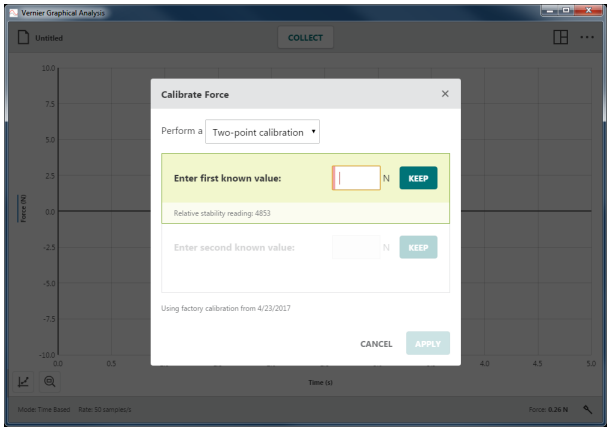
Click or tap a sensor meter, Force: 0.25 N, to access tools that modify the sensor readings. The tools include options to calibrate, zero, reverse, and change units. Which tools are available depend on the connected sensor as not all options are appropriate for all sensors.



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.

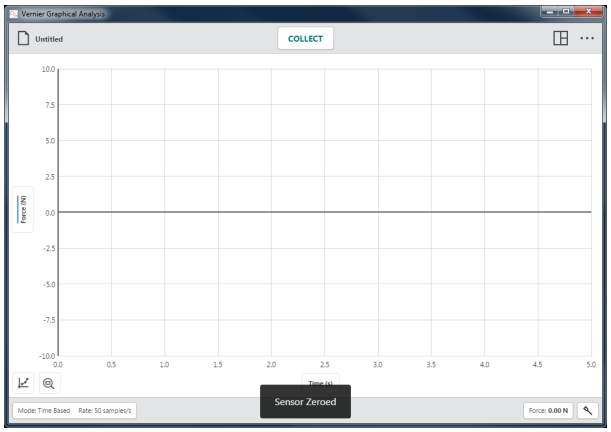
TIP! *Detailed calibration instructions are provided in sensor user manuals available online at* www.vernier.com/manuals



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 has already been collected.*

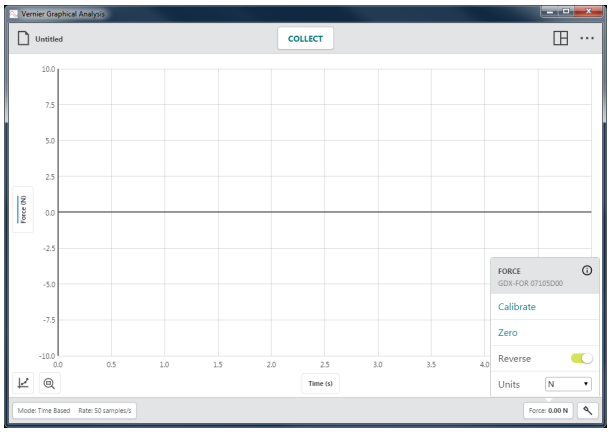


Reverse

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

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

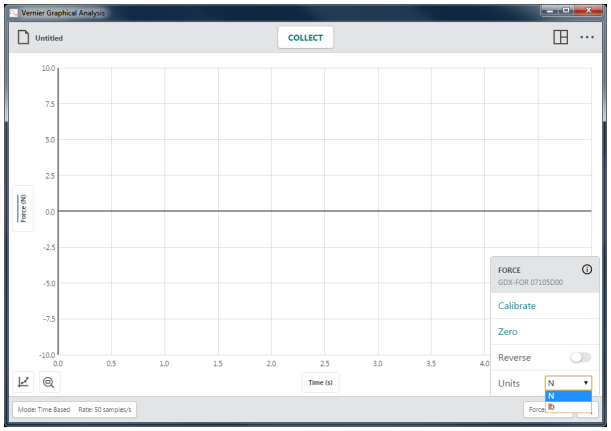
TIP! *Previously collected data is not changed when* Reverse *is toggled.*



Units

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

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

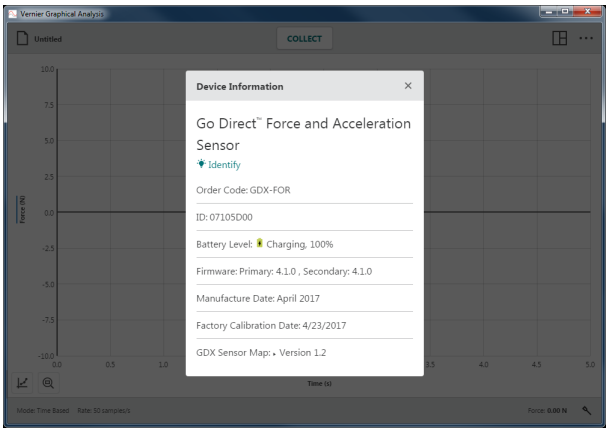


Device Information, ⓘ

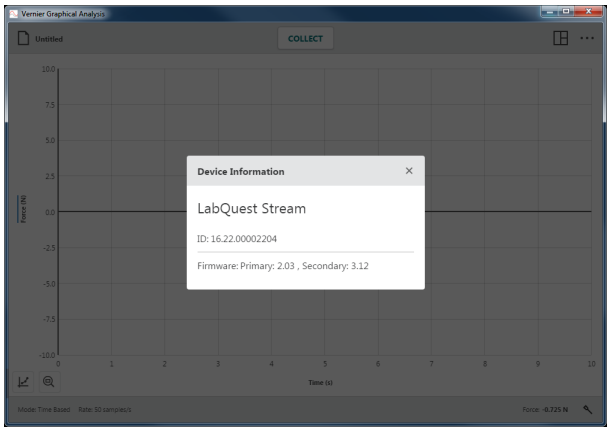
Click or tap ⓘ to view information about the sensor.

For Go Direct® sensors, device information includes the sensor ID, battery-level status, firmware version, sensor map version, manufacture date, and factory calibration date.

TIP! *Click or tap* Identify *to flash the sensor's LED.*



For sensors connected using a LabQuest® interface (LabQuest 2, LabQuest Stream®, LabQuest Mini, or Go!Link®), the information provided is for the interface and not the sensor itself.



Setting up the Sensor – 🔧

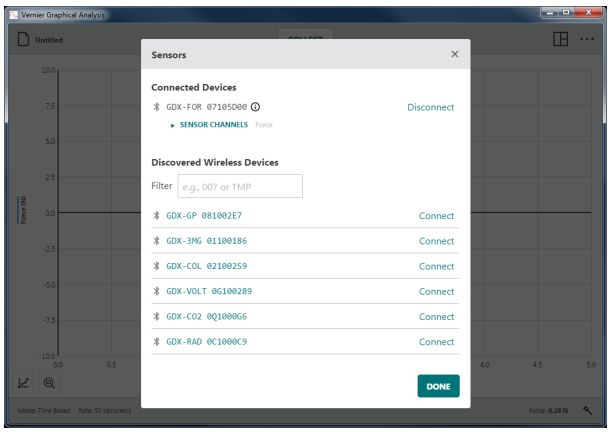
Click or tap 🔧 to access the Sensors dialog. Use this dialog to review which devices are connected, add or remove wireless sensors or interfaces, modify the sensor channel configuration (available on some Go Direct sensors), and view connected device details.

Connected Deivces

This section shows all connected sensors and interfaces (USB and wireless).

Supported devices include LabQuest sensor interfaces (LabQuest 2, LabQuest Stream, LabQuest Mini, Go!Link), Go Direct sensors (via USB or Bluetooth® wireless technology), Go!Temp®, and Go! Motion®.

TIP! *You can click or tap* ⓘ *to view device information.*



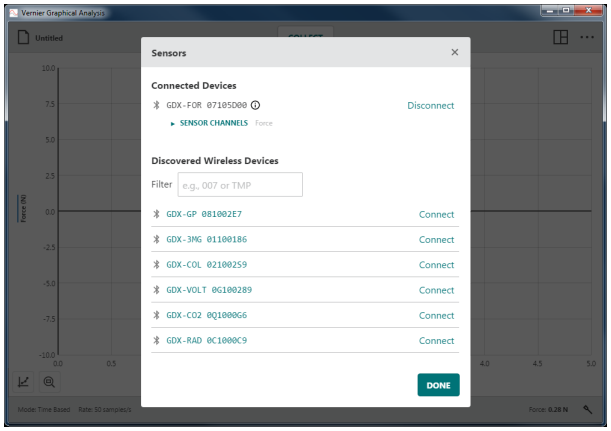
- **Disconnecting Sensors**

  For wireless sensors, click or tap Disconnect to end the connection. For USB sensors and interfaces, unplug the USB cable from your device to disconnect the sensor.

- **SENSOR CHANNELS**

  Some Go Direct sensors have multiple sensor channels available, not all of which are active by default.

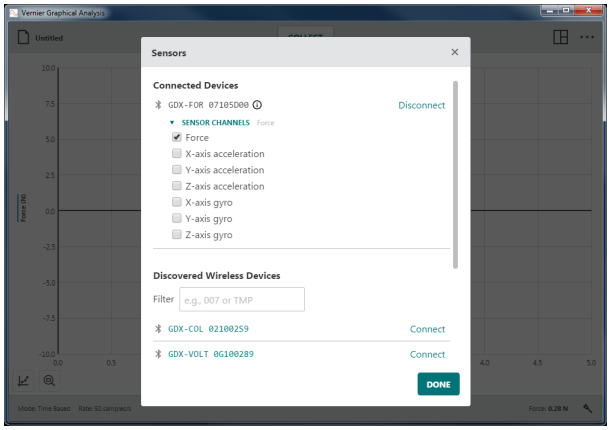
  When a sensor has multiple sensor channels, a list of active sensor channels is shown.



  Click or tap SENSOR CHANNELS to view the full list of channels available for that sensor.

  Click or tap a channel to toggle its selection. There must be at least one channel selected in order to continue.

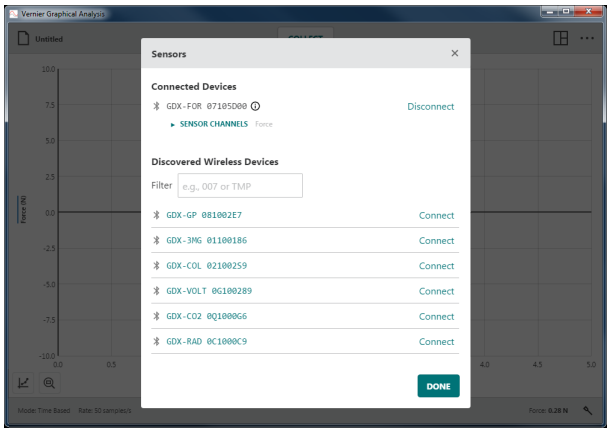
  TIP! *Each active sensor channel will have a corresponding sensor meter displayed on the bottom toolbar.*



Discovered Wireless Deivces

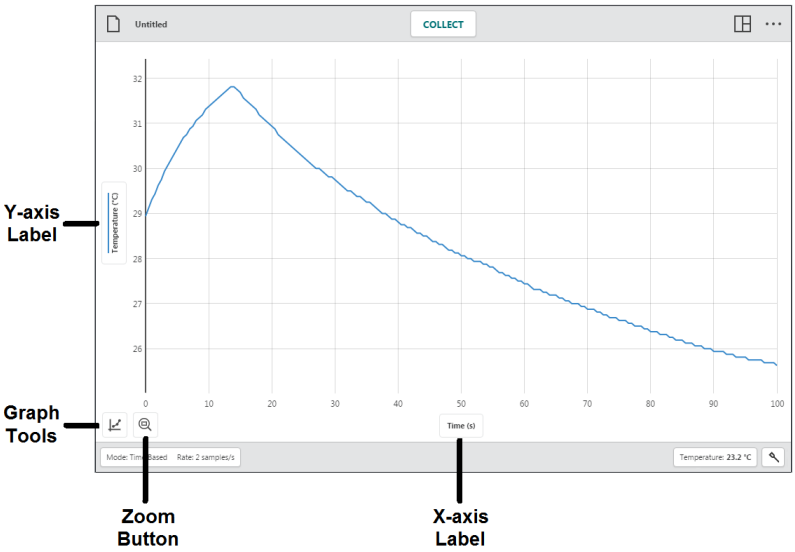
This section of the dialog shows all available wireless sensors that are within range of your device. The sensors are uniquely named using their order code and serial number. Click or tap Connect to connect to the sensor.

TIP! *You can filter the device list by entering any part of a device name (serial number or order code) into the filter.*



When the Sensor Setup button is shown with a red dot, , one or more sensors have out-of-date firmware. For instructions on updating the firmware, see Updating the Firmware on a Go Direct Sensor at the end of this document.

VI. GRAPH BUTTONS

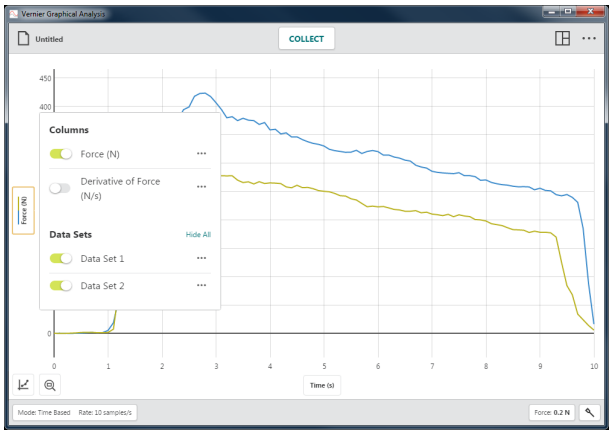


Axes Labels – Time (s)

Vertical-axis (y-axis) Label

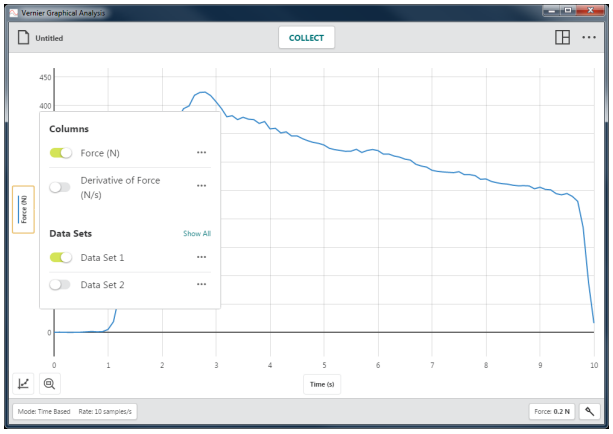
Click or tap the vertical-axis (y-axis) label to change the data that is plotted on the graph. Click or tap a column name to add or remove the column data from the graph.

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



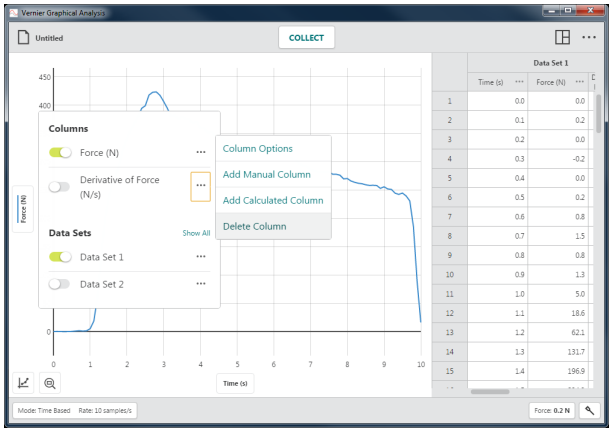
Click or tap a data set name to show or hide the selected column data for a specific data set.

TIP! *Use the* Show All *and* Hide All *options to quickly show or hide data from every data set.*



- **Column Tools**

  Click or tap ··· next to a column name to access the column tools. The available options depend on the type of experiment you are doing, as well as the type of column you have. Options include Column Options, Add Manual Column, Add Calculated Column, and Delete Column.



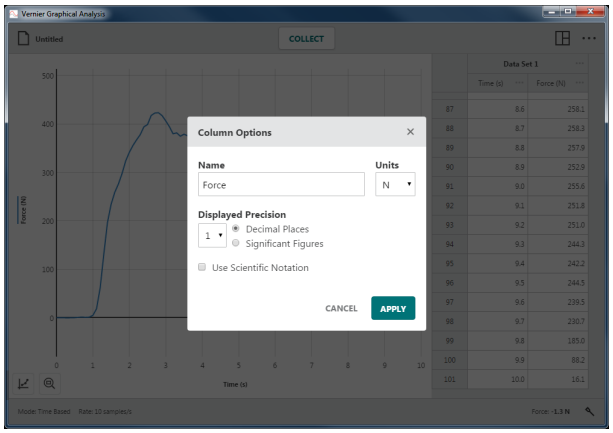
  TIP! *Column tools are not available for* Data Sharing *experiments. Columns are modified on the Data Sharing source only.*

TIP! *Since data sets are symmetric, columns added or modified in one data set are likewise added or modified in all data sets.*

Column Options

Choose Column Options to change the column name and displayed precision.

TIP! *For manual and calculated columns, you can also change the units from this dialog.*

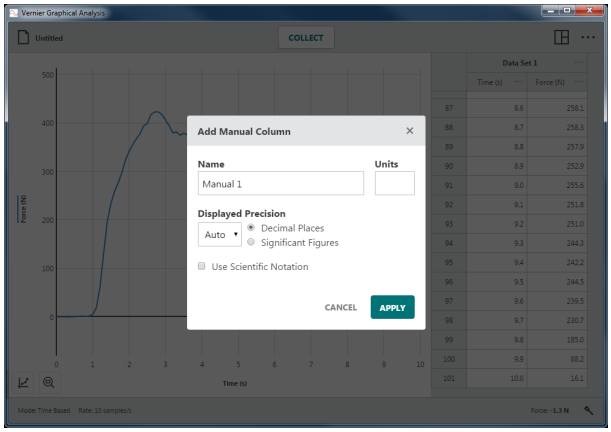


Add Manual Column

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.

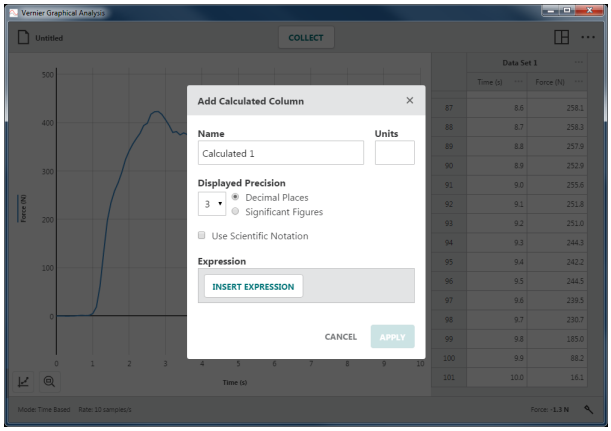
TIP! *New manual columns are not shown on the graph automatically. Click or tap the vertical-axis (y-axis) label to change what is plotted on your graph.*



Add Calculated Column

Choose Add New Calculated Column to create a new column with values that are based on other columns through a mathematical formula.

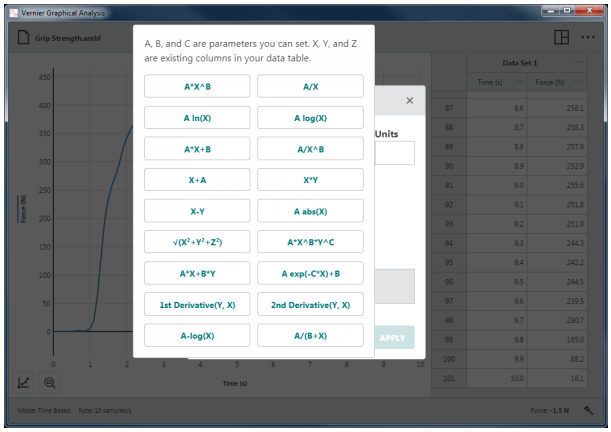
You can modify the column name, add units, and adjust the display precision of the new column as desired.



Click or tap INSERT EXPRESSION to view your expression options.

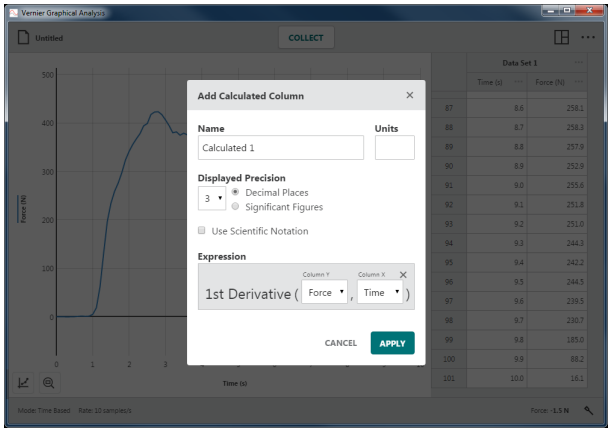
Select the desired expression to use for your calculated column.

TIP! A *and* B *represent constants.* X, Y, *and* Z *represent data columns from your data table.*



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

TIP! *New calculated columns are not shown on the graph automatically. Click or tap the vertical-axis (y-axis) label to change what is plotted on your graph.*

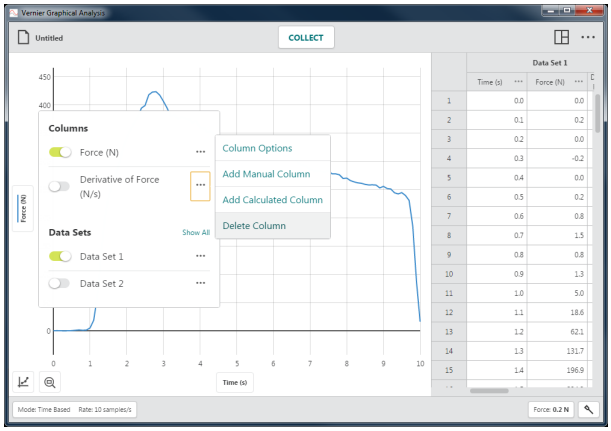


Delete Column

Choose Delete Column to remove Manual or Calculated Columns. Sensor and time columns cannot be deleted.

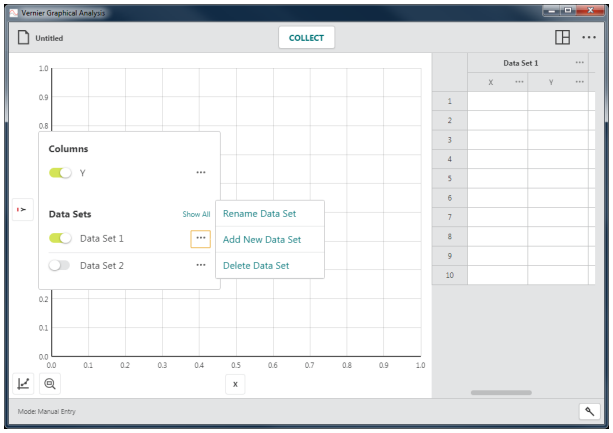
TIP! X *and* Y *data columns from a* Manual Entry Experiment *cannot be deleted, but they can be renamed using Column Options.*

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



- **Data Set Tools**

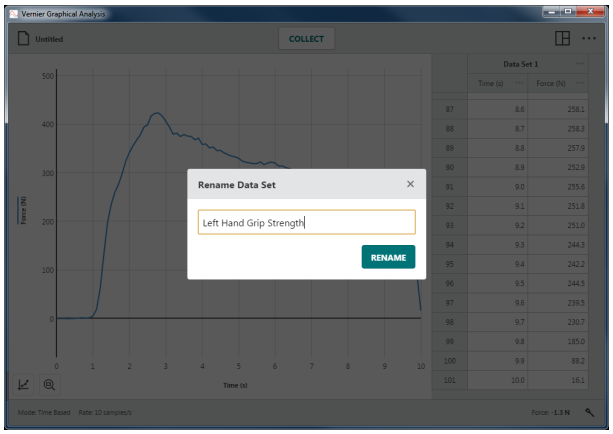
  Click or tap ··· next to a data set name to access the data set tools. The available options depend on the type of experiment you are doing. Options include Rename Data Set, Add New Data Set, and Delete Data Set.



Rename Data Set

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

TIP! *This option is not available for* Data Sharing *experiments. Data set names are changed on the Data Sharing source only.*

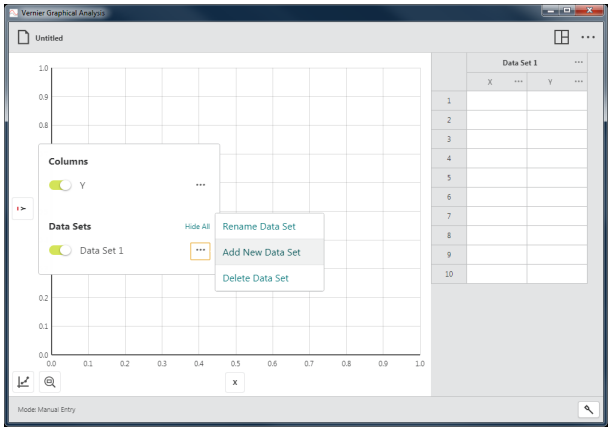


Add New Data Set

Choose Add New Data Set to add an additional data set to a manual experiment.

The new data set will have the same columns and configurations as the original data set.

TIP! *This option is only available for* Manual Entry *experiments.*

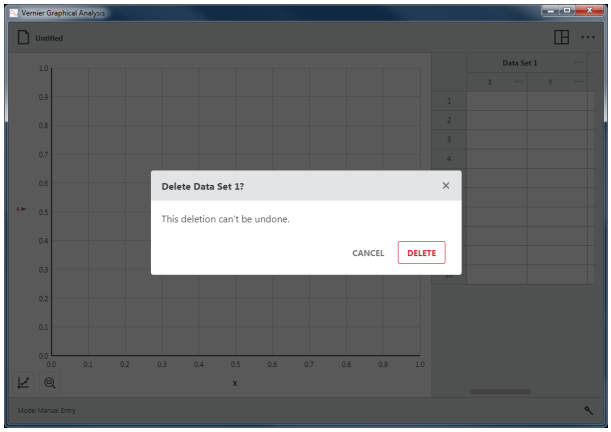


Delete Data Set

Choose Delete Data Set to remove a data set.

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

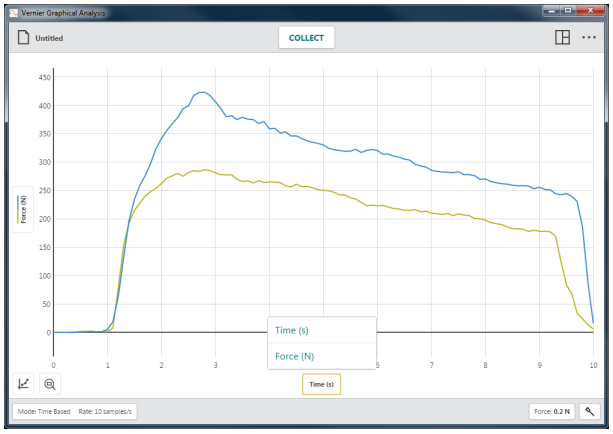
TIP! *The last created data set cannot be deleted; however, any entered or collected data will be cleared.*



Horizontal-Axis (x-axis) Label

Click or tap the horizontal-axis (x-axis) label 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, that column will be removed from the vertical axis (y-axis).*

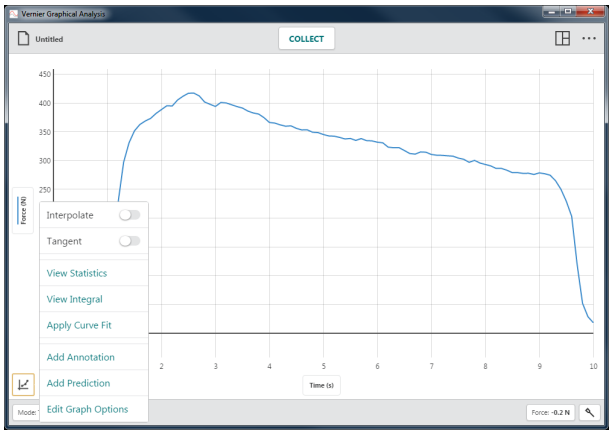


Graph Tools –

Graph Tools are graph-specific tools used to analyze data or modify the graph appearance.

The Graph Tools include Interpolate, Tangent, View Statistics, View Integral, Apply Curve Fit, Add Annotation, Add Prediction, Add Graph Match (motion sensors only), and Edit Graph Options.

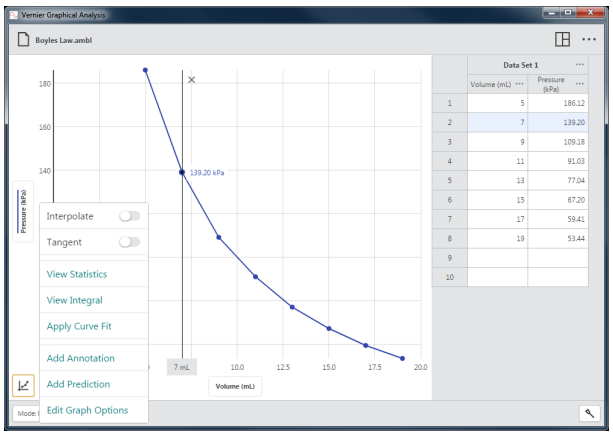
TIP! *Graph tool selections only apply to the graph from which they are accessed.*



Interpolate

The interpolate function affects the behavior of the examine cursor when examining data. Interpolate is off by default.

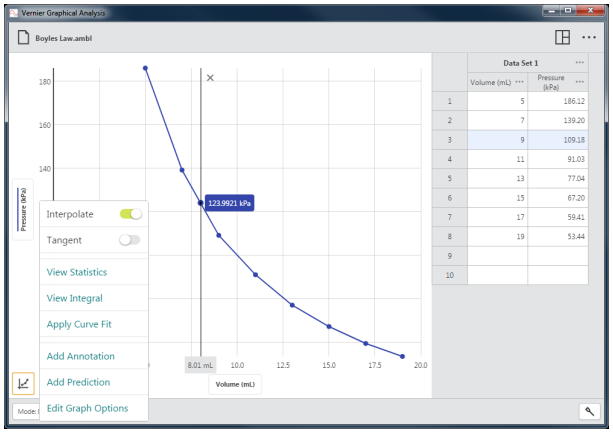
While interpolate is off, the displayed examine values are for plotted data points. As you move the examine line, the value of the nearest data point is displayed.



While interpolate is 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**

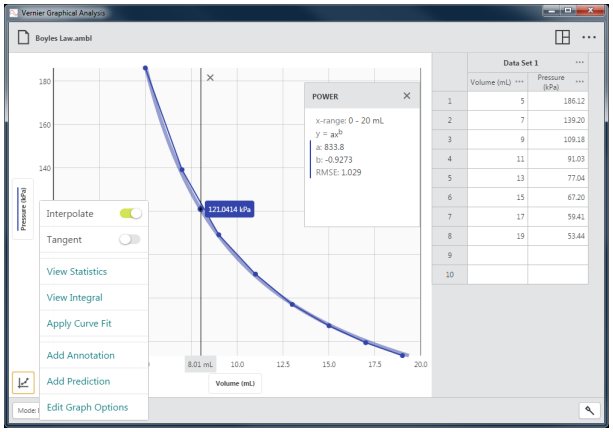
  When there is no curve fit, the examine cursor follows the straight line path between two consecutive points.



- **Interpolate with a Curve Fit**

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

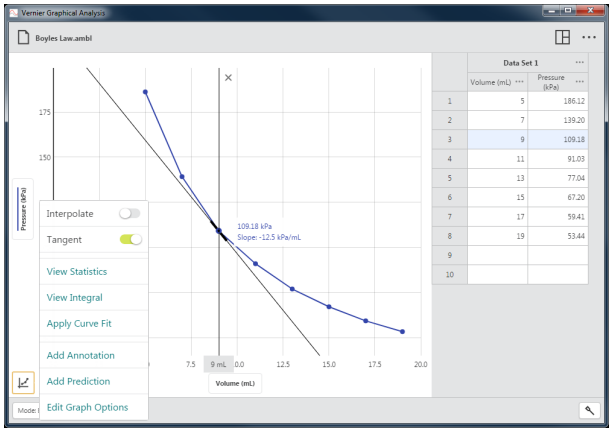
  TIP! *To examine data points beyond your data (extrapolate), you must have a curve fit plotted on the graph and interpolate turned on.*



Tangent

Choose Tangent to calculate 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.

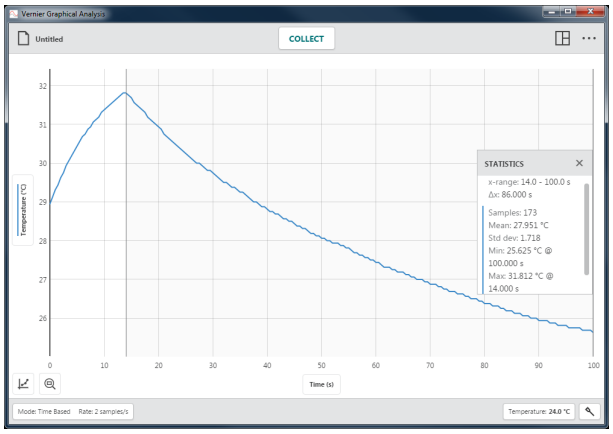
TIP! *You cannot use Interpolate and Tangent at the same time. Choosing one will de-select the other.*



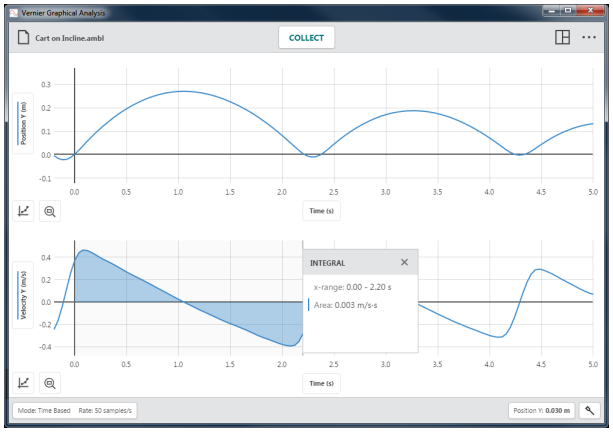
View Statistics

Choose View Statistics 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.

TIP! *The statistics are based on all of the data when* View Statistics *is selected without first selecting a region.*



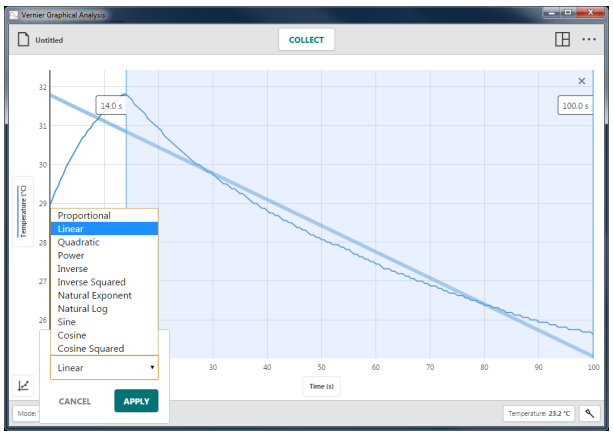
View Integral



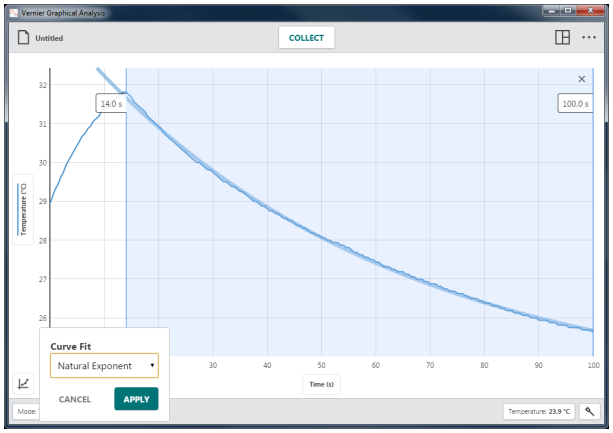
Choose View Integral to calculate the numerical integral (area) associated with your data. The associated area is shaded and the value is displayed. Regions above the horizontal-axis (x-axis) are positive, while regions below are negative. Areas for all plotted columns are calculated.

TIP! *Integrals are based on all of the data when* View Integral *is selected without first selecting a region.*

Apply Curve Fit



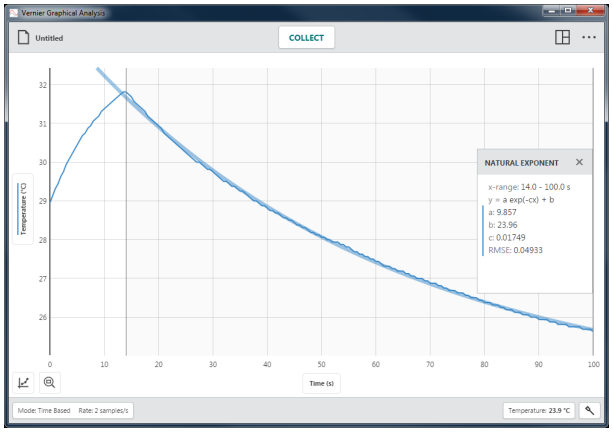
Choose Apply Curve Fit to find the equation of the best-fit curve based on your data. Curve fit models include Proportional, Linear, Quadratic, Power, Inverse, Inverse Squared, Natural Exponent, Natural Log, Sine, Cosine, and Cosine Squared.



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

TIP! *Curve fits are based on all of the data when* Apply Curve Fit *is selected without first selecting a region.*

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

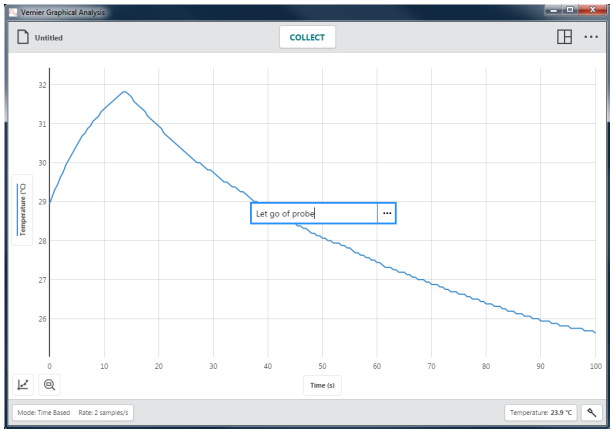


The curve fit details dialog includes the RMSE (root mean square error), a measure of how well the fit matches the data.

TIP! *You can reposition the statistics, integral, or curve fit details dialogs by dragging them up and down the right boundary of the associated region.*

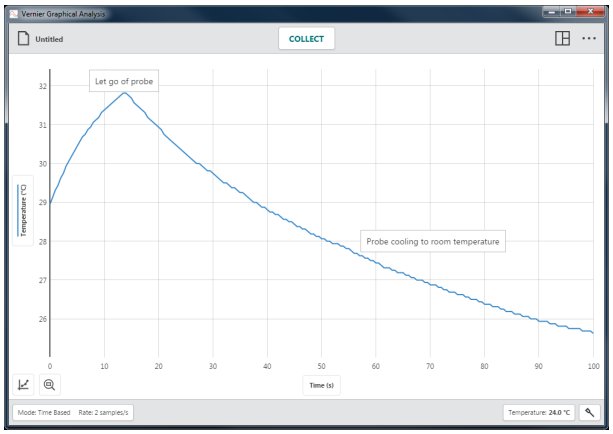
Add Annotation

Choose Add Annotation to add text labels to your graph.



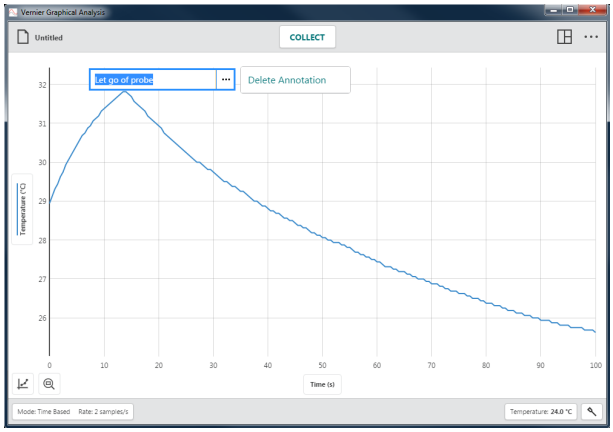
Click-and-drag or touch-and-drag an annotation to reposition it on the graph.

TIP! *You can add multiple annotations to a graph.*



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

Click or tap ··· to delete the annotation.



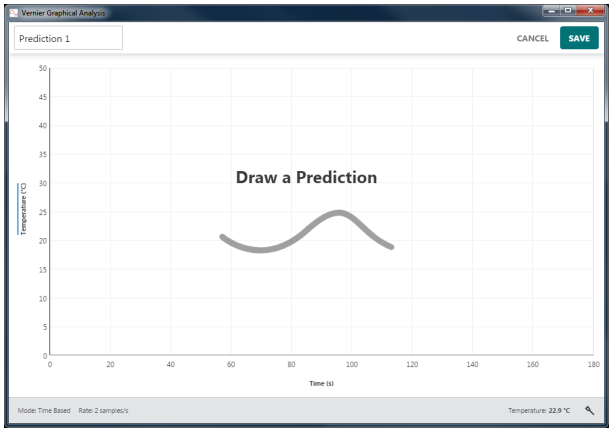
Add Prediction

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.*

Choose Add Prediction to sketch a prediction on your graph.

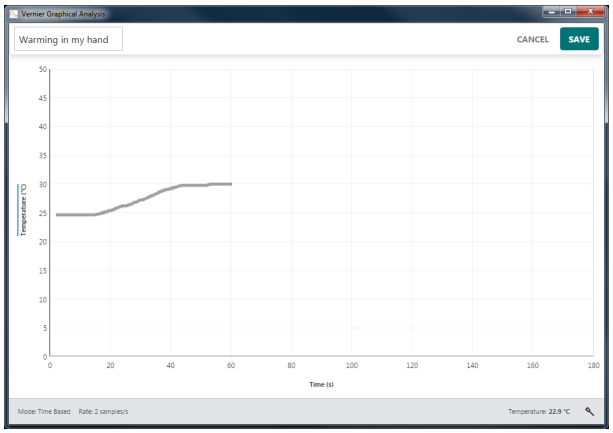
If you are in 2 Graphs, 3 Graphs, or Graph and Table view, the graph to which you are adding the prediction will expand to full screen while the Add Prediction tool is active.



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

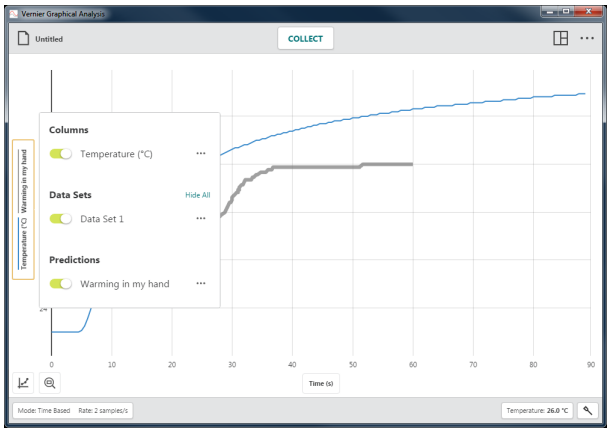
Name the prediction if desired, then click or tap SAVE to add the prediction to your graph.

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

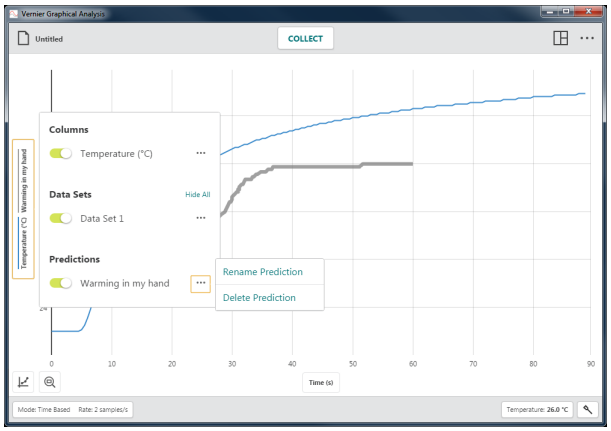


Collect data to compare your predication with real data.

To hide a prediction from the graph, click or tap the vertical-axis (y-axis) label and de-select the prediction.



To delete a prediction, click or tap the vertical-axis (y-axis) label, then click or tap ••• and select Delete Prediction.

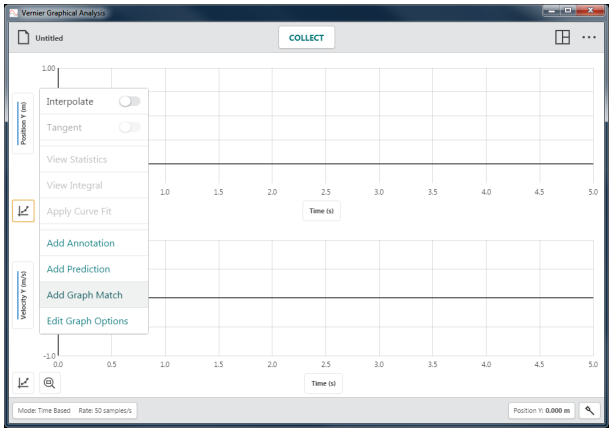


Graph Match

Choose Graph Match to have a position or velocity target drawn on the graph.

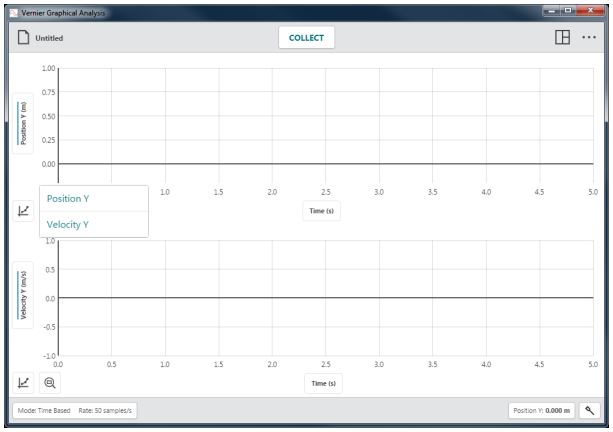
The Graph Match option is only available when a Motion Detector, Motion Encoder, or Sensor Cart is connected.

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



Choose a Position or Velocity target to match.

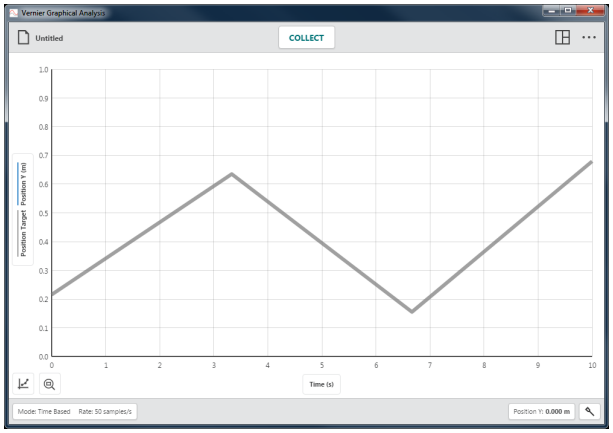
TIP! *When working with students that have never done a graph match, start with a position match.*



- **Position Match**

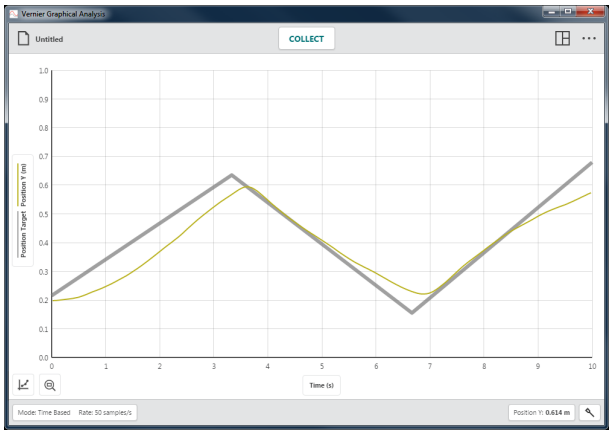
  A Position match will contain three linear segments.

  TIP! *The Position Target will always display in* 1 Graph *view regardless of the number of graphs shown when* Graph Match *is selected.*



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

TIP! *To get a different match, select* Graph Match ▸ Position *again.*

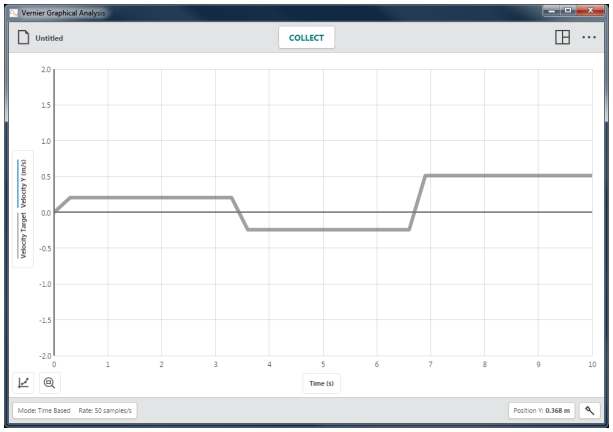


- **Velocity Match**

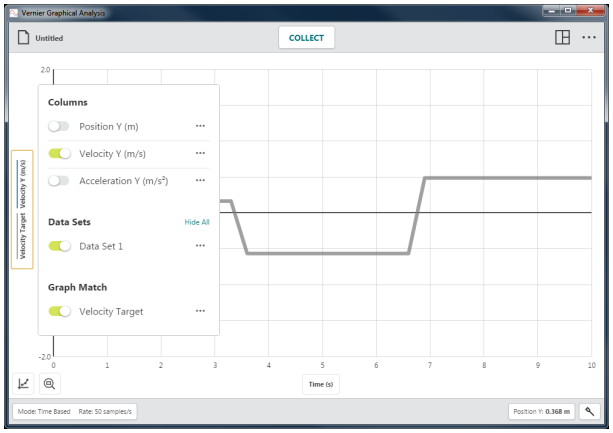
  A Velocity match will contain three horizontal (constant velocity) segments.

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

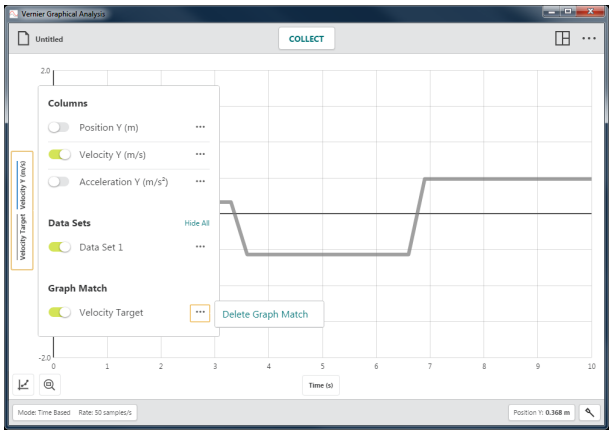
  TIP! *The Velocity Target will always display in* 1 Graph *view regardless of the number of graphs shown when* Graph Match *is selected.*



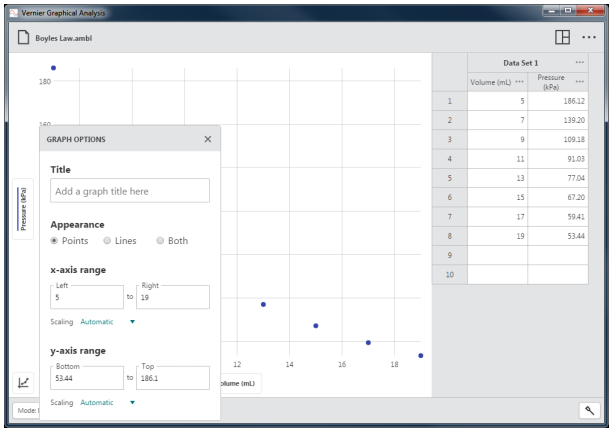
To hide a Position or Velocity Target from the graph, click or tap the vertical-axis (y-axis) label and de-select the Graph Match target.



To delete a Graph Match target, click or tap the vertical-axis (y-axis) label, then click or tap ••• and select Delete Graph Match.



Edit Graph Options

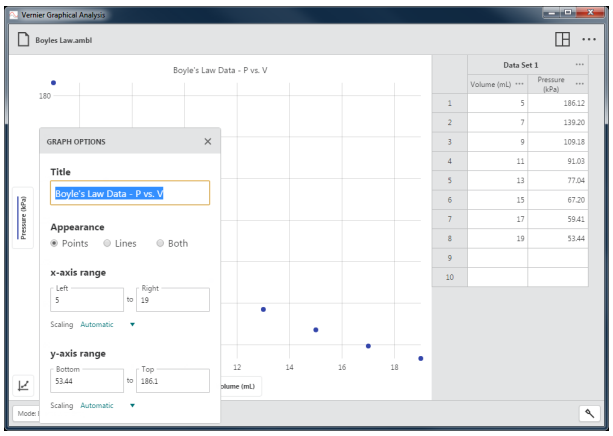


Choose Edit Graph Options to access graph configuration tools. Options include adding a title, changing the graph appearance, manually scaling the graph, and changing the graph scaling behavior.

TIP! *Changes to the* Graph Options *values only apply to the graph from which the tool was accessed. Changes made to one graph are not automatically applied to other graphs in the view.*

- **Title**

  You can choose to add a title to your graph. The title will appear centered above the graph.

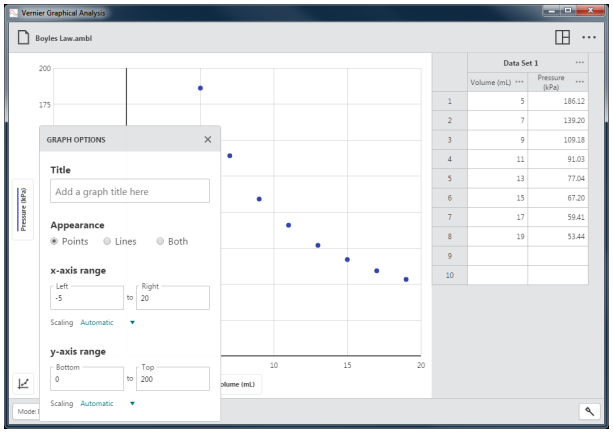


- **Appearance**

  Points

  Choose Points to show data as unconnected dots.

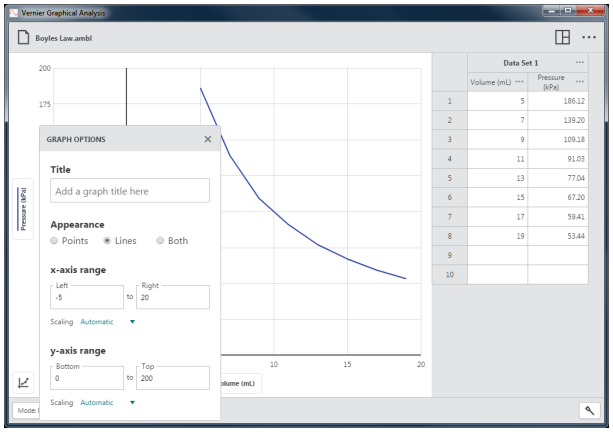
  This is the default option for manual experiments and sensor experiments that use event-based, drop counting, and photogate timing modes.



Lines

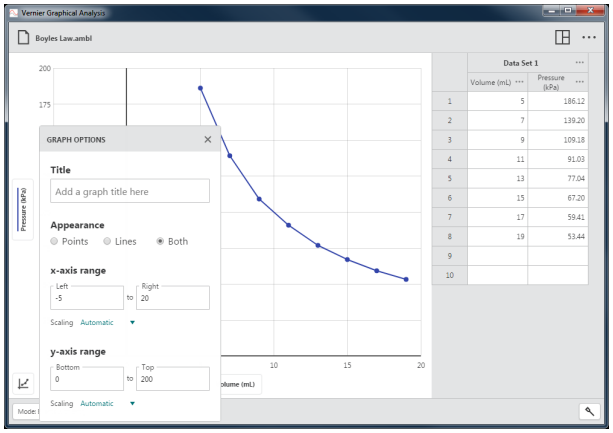
Choose Lines to show linear segments drawn between the data points.

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



Both

Choose Both to show data as dots connected by linear segments. While this appearance option is not displayed by default, it is always available.



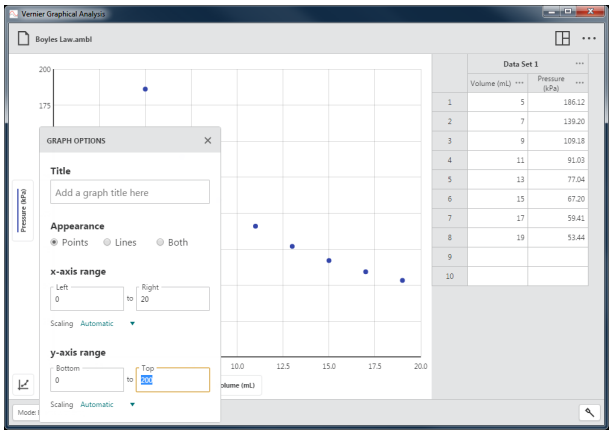
- **X-Axis** and **Y-Axis Range**

  Manually configure the graph range to display the data as desired.

  Scaling – Automatic

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

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

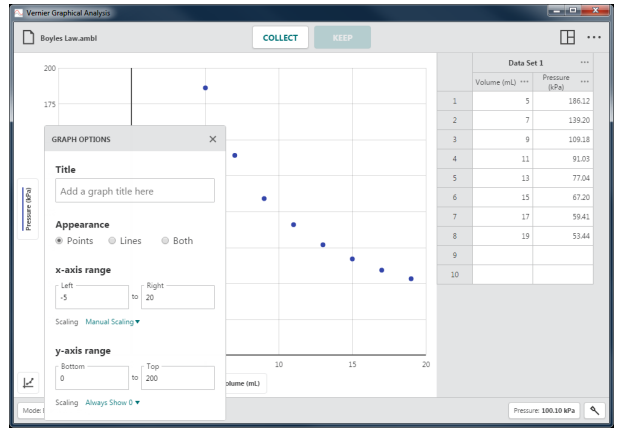


Scaling – Always Show 0

This option will scale the graph to include 0 for that axis. This setting does not change the automatic behavior related to scaling the graph larger but is respected when you manually autoscale the graph.

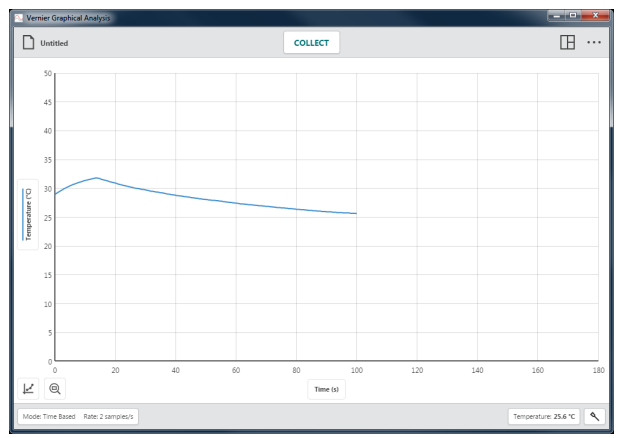
Scaling – Manual

This option disables the automatic behavior related to scaling the graph larger during collection but is not respected when you manually autoscale the graph.



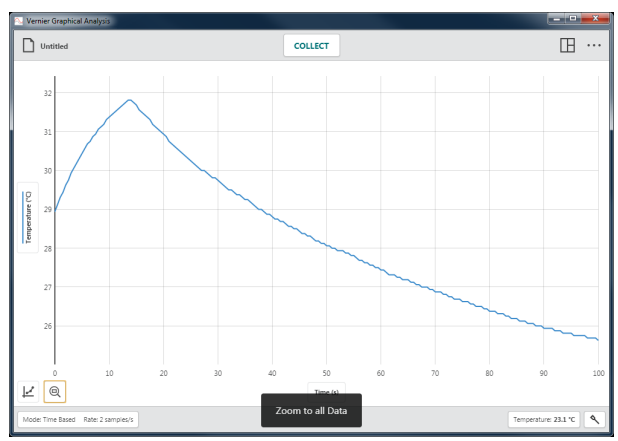
Zoom –

Use the Zoom button to quickly rescale the graph. The scaling behavior depends on the selection of data.



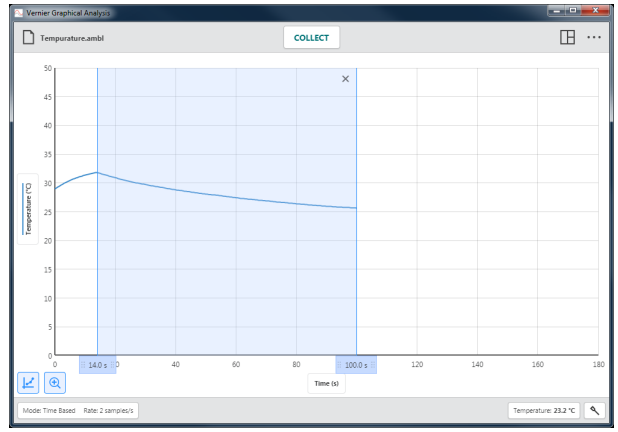
When there are no selected data, click or tap to rescale the graph to fit all data points.

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



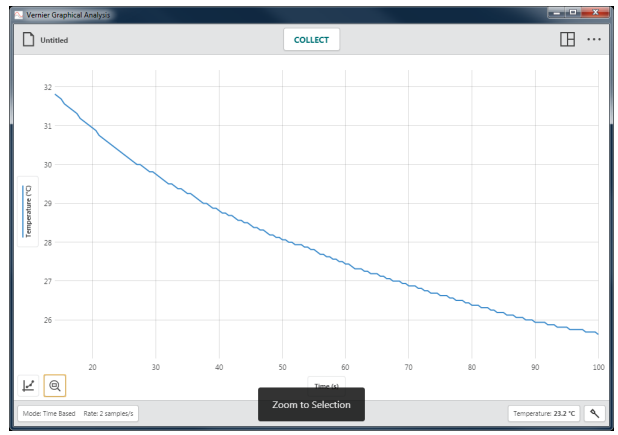
To scale the graph to a specific section of your data, click-and-drag or touch-and-drag across the graph to select the desired region.

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 to rescale the graph to fit the selection.

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

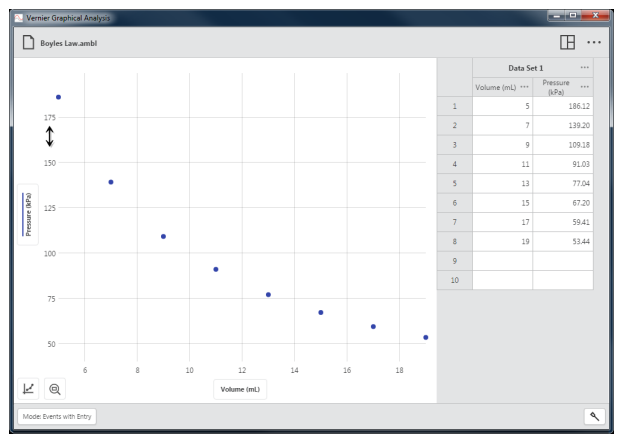


Other Tools Available from the Graph

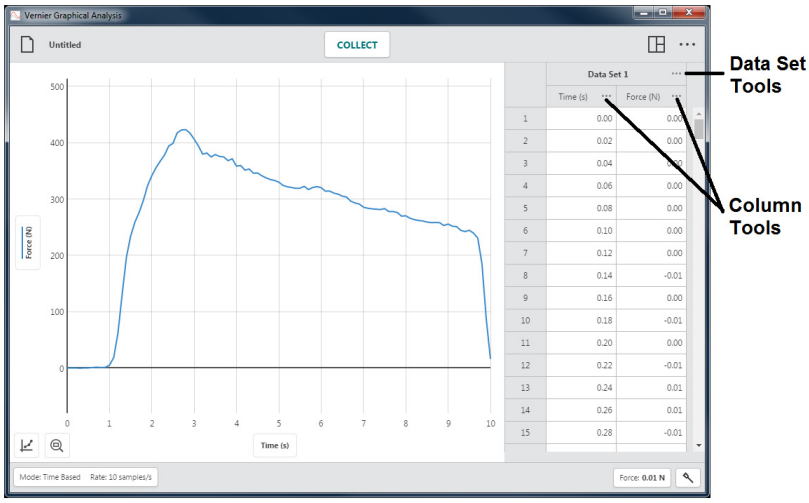
Panning the Graph

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

TIP! *In addition to panning, touch-screen devices can use a two-finger pinch gesture to rescale the graph.*

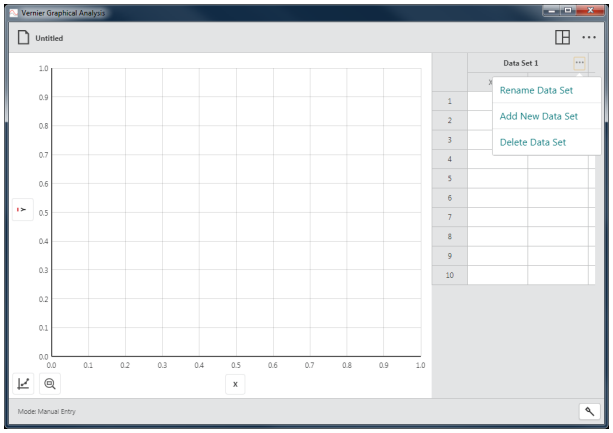


VII. TABLE BUTTONS



Data Set Tools – •••

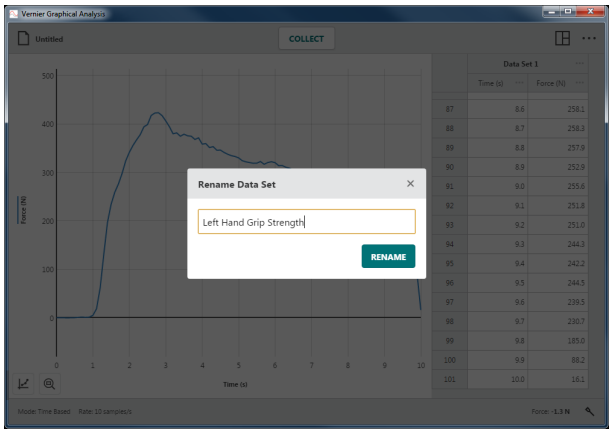
Click or tap ••• next to a data set name to access the data set tools. The available options depend on the type of experiment you are doing. Options include Rename Data Set, Add New Data Set, and Delete Data Set.



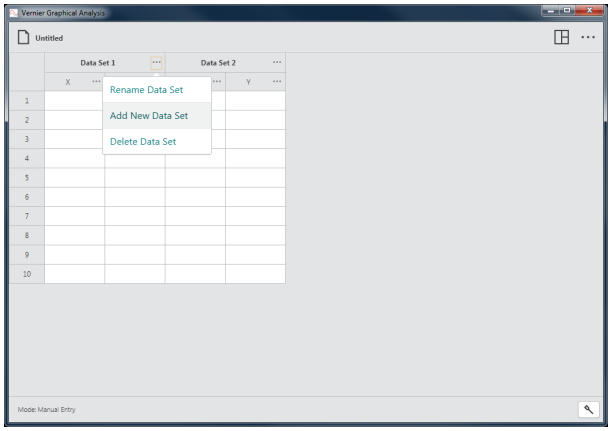
Rename Data Set

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

TIP! *This option is not available for* Data Sharing *experiments. Data set names are changed on the Data Sharing source only.*



Add New Data Set

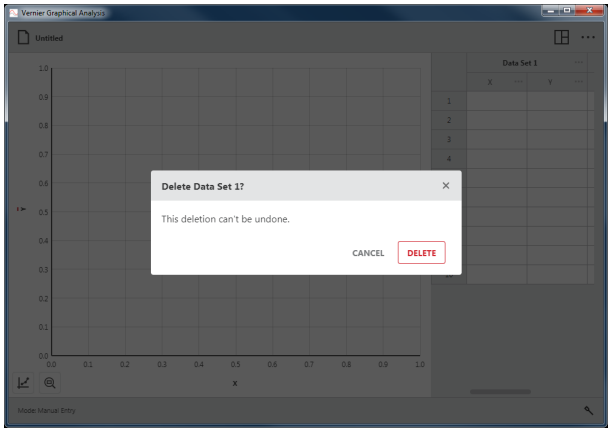


Choose Add New Data Set to add an additional data set to a manual experiment.

The new data set will have the same columns and configurations as the original data set. The new data set is always added after the last data set.

TIP! *This option is only available for* Manual Entry *experiments.*

Delete Data Set

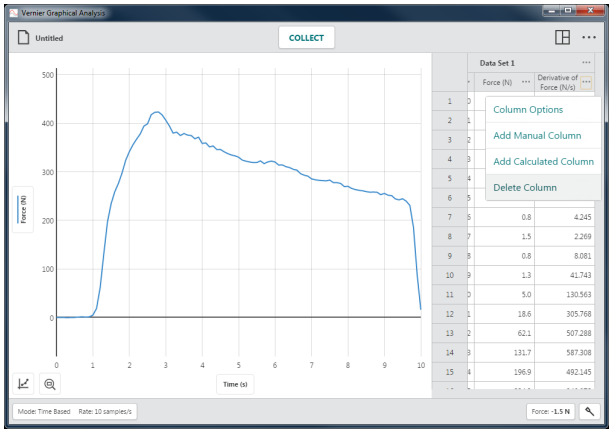


Choose Delete Data Set to remove a data set.

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

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

Column Tools – •••



Click or tap ••• next to a column name to access the column tools. The available options depend on the type of experiment you are doing, as well as the type of column you have. Options include Column Options, Add Manual Column, Add Calculated Column, and Delete Column.

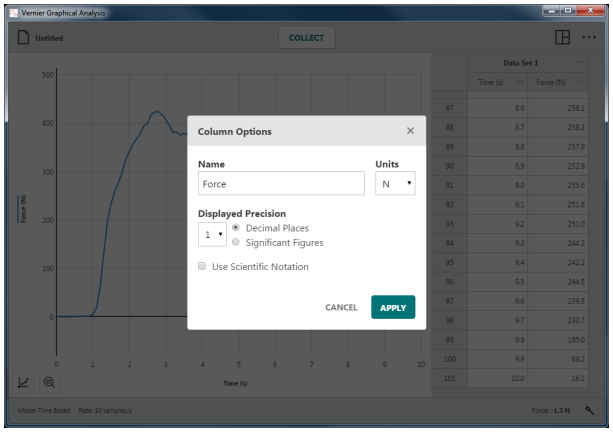
TIP! *Since data sets are symmetric, columns added or modified in one data set are likewise added or modified in all data sets.*

TIP! *Column tools are not available for* Data Sharing *experiments. Columns are modified on the Data Sharing source only.*

Column Options

Choose Column Options to change the column name and displayed precision.

TIP! *For manual and calculated columns, you can also change the units from this dialog.*

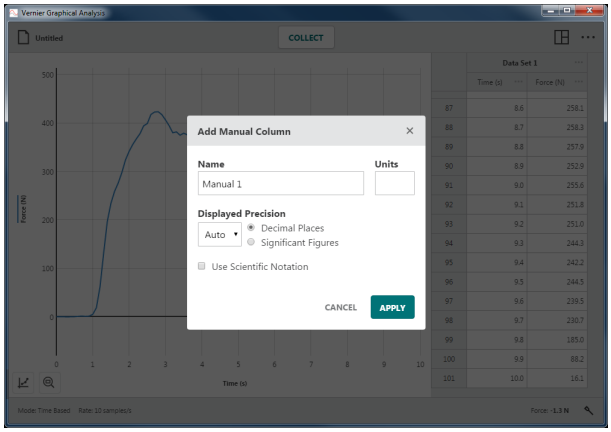


Add Manual Column

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.

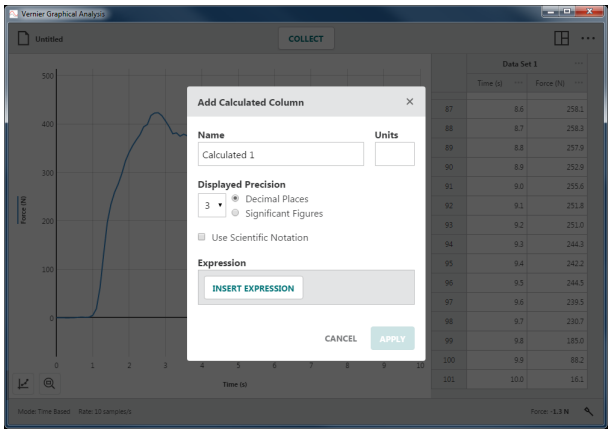
TIP! *The new column is added to the right of the column used to access the column tools.*



Add Calculated Column

Choose Add New Calculated Column to create a new column with values that are based on other columns through a mathematical formula.

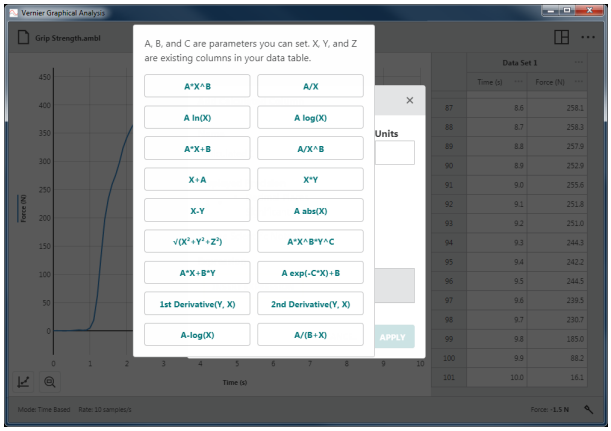
You can modify the column name, add units, and adjust the display precision of the new column as desired.



Click or tap INSERT EXPRESSION to view your expression options.

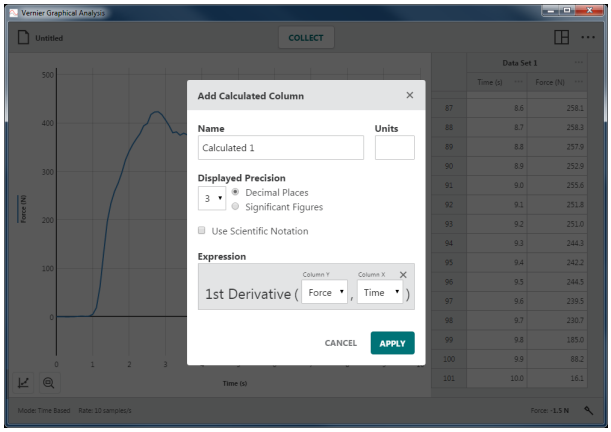
Select the desired expression to use for your calculated column.

TIP! A *and* B *represent constants.* X, Y, *and* Z *represent data columns from your data table.*



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

TIP! *The new calculated column will appear to the right of the column used to access the column tools.*

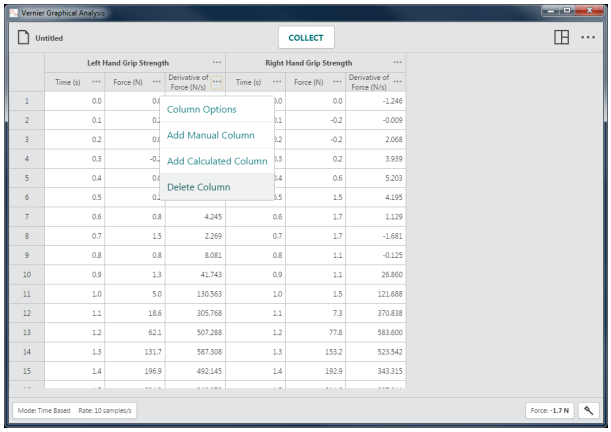


Delete Column

Choose Delete Column to remove Manual or Calculated Columns. Sensor and time columns cannot be deleted.

TIP! X *and* Y *data columns from a* Manual Entry Experiment *cannot be deleted, but they can be renamed using Column Options.*

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



Other Tools Available from the Table – Cut Copy Paste

You can use edit tools, such as Cut, Copy, and Paste to modify the contents of a data table.

Edit a Cell

Double-click or double-tap a manual column cell to edit the cell. Cells from sensor columns, time columns, and calculated columns cells are locked from editing to discourage data manipulation.

TIP! *The event-based "Event" column is a manual column that can be edited.*

Using the Cut, Copy, and Paste Tools

You can copy data to and from the system clipboard on your computing device. You can copy a single cell, a range of cells, a single row or column, a range of rows or columns, a single data set, or a range of data sets.

Select Cells

- Click or tap a single 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.

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** 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** and **Android** (and other touch-screen devices): Long-touch within the selection and select Cut

TIP! *When using* Cut*, data from sensor columns, time columns, and calculated columns will not be deleted from the data table.*

Paste from the Clipboard

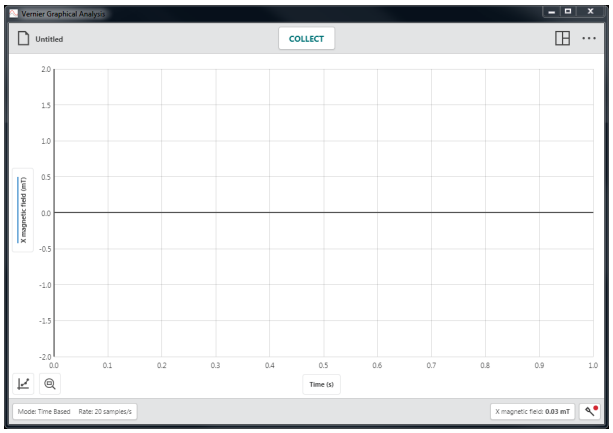
- **Windows**: Right-click and select Paste (or Ctrl-V)
- **macOS**: Command-V (⌘-V)
- **Chromebook**: Alt-click and select Paste (or Ctrl-V)
- **iOS** and **Android** (and other touch screen devices): Long-touch within the selection and select Paste

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

VIII. UPDATING THE FIRMWARE ON A GO DIRECT SENSOR –

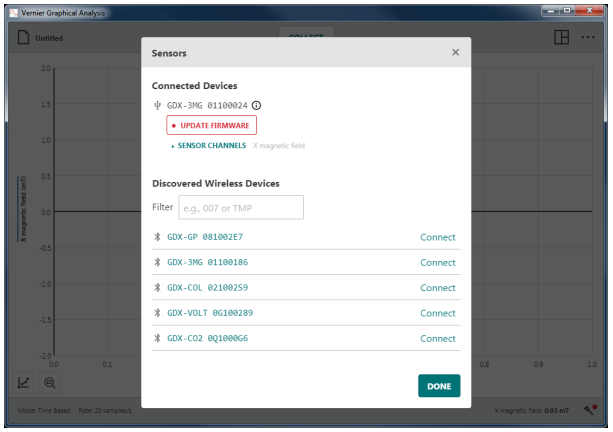
Graphical Analysis 4 automatically checks the firmware version of a connected sensor when a sensor is connected. When a newer version of firmware is available, the Sensor Setup button is displayed with a red dot, .

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.



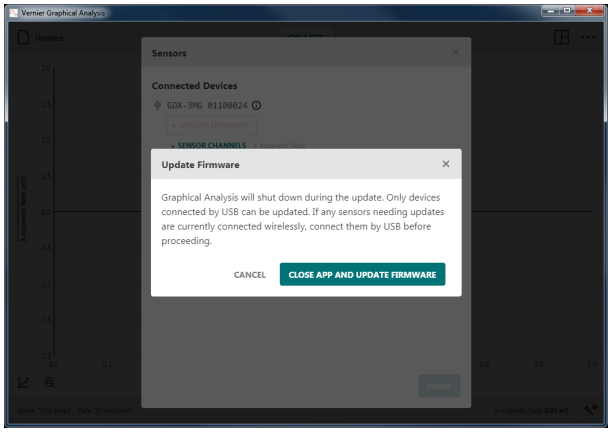
Click or tap to access the Sensors dialog.

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

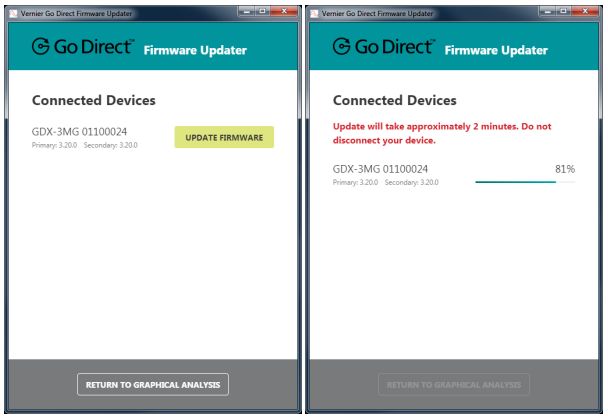


Click or tap UPDATE FIRMWARE to start the firmware update for that sensor.

Since 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.

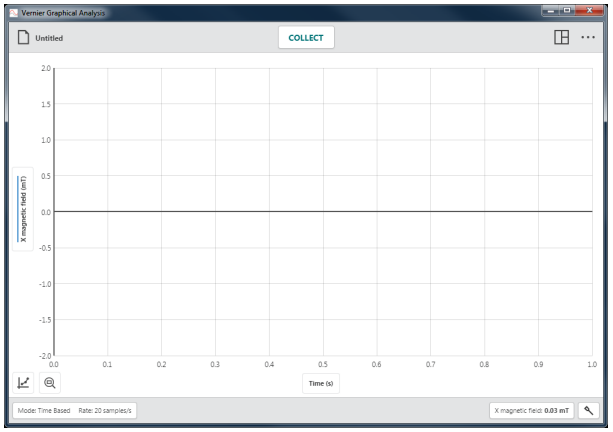


Click or Tap UPDATE FIRMWARE to update the sensor. Firmware updates take about two minutes to complete. Progress is indicated via a progress meter next to each sensor being updated.



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

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



IX. GETTING ADDITIONAL HELP

For access to user manuals, forums, and our technical information library, please visit our website at www.vernier.com/support

If you are located in the United States or Canada, you may also contact Vernier directly:

888.837.6437
support@vernier.com
www.vernier.com

Otherwise, please contact Vernier International:

941.349.1000
info@vernier-intl.com
www.vernier-intl.com

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