

Wireless Dynamics Sensor System

(Order Code WDSS)



The Wireless Dynamics Sensor System (WDSS) allows you to take data from a three-axis accelerometer, force sensor, and altimeter, using a Bluetooth® wireless connection to your computer. It is the perfect tool for dozens of physics and physical science experiments such as:

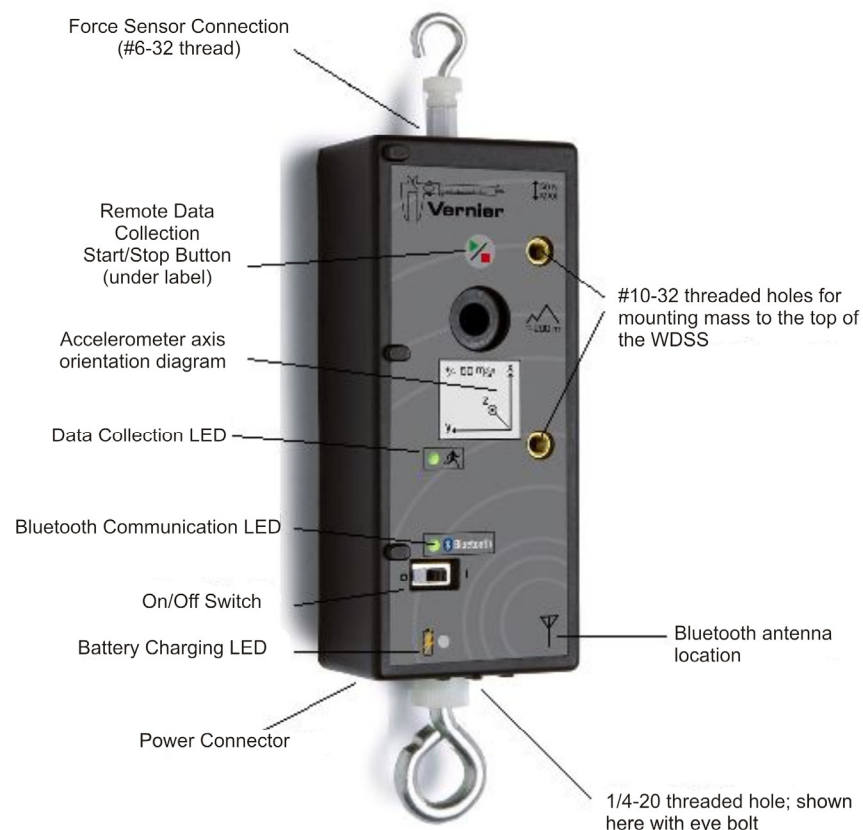
- Studying the motion of a dynamics cart on a track. The WDSS can be mounted on a cart, avoiding the problems associated with wires when using conventional accelerometers and force sensors.
- Amusement park and playground rides. The WDSS has internal memory and can collect acceleration and altitude data (to get a profile of the ride) for over 100,000 readings over several minutes. You can store multiple runs before retrieving the data.
- Studying simple harmonic motion by mounting the WDSS as an oscillating mass hanging from a spring.
- Studying accelerations of skateboarders or dancers with a WDSS mounted on them while data are recorded on a nearby computer.
- Studying forces and accelerations during circular motion by mounting the WDSS on a turntable or bicycle wheel.

In addition, you can use the WDSS to do other traditional experiments that you do with conventional accelerometers and force sensors. You will find more information on experiments you can do with the WDSS later in this manual.

NOTE: Vernier products are designed for educational use. Our products are not designed nor recommended for any industrial, medical, or commercial process such as life support, patient diagnosis, control of a manufacturing process, or industrial testing of any kind.

The WDSS hardware

The photo below shows the Wireless Dynamics Sensor System with the key parts identified.



- **On/Off Switch** The switch controls the power to the WDSS. Turn the switch off when you are not using the WDSS. Data stored in the WDSS memory will not be lost when you turn off the power.
- **Battery Charging LED** This yellow LED indicates when the WDSS batteries are being charged. The LED will come on as soon as the WDSS is plugged in unless the battery is already 100% charged. The LED will go off when the battery becomes fully charged.
- **Power Connector** This connector is used with a 6 V DC, center-negative power supply, like the one included with the WDSS or with a Vernier LabPro® interface. This power supply is Vernier order code IPS.

- **Data Collection LED** This LED indicates when data are being collected or ready to be collected by the WDSS. When the WDSS is communicating with Logger *Pro*[®], and ready to take live data, the Data Collection LED is green. This LED also gives feedback as you start remote data collection. When remote data collection starts, the LED will start flashing green. You may also see this LED flash red. This means that data are being moved around in the WDSS internal memory. Do not turn off the WDSS power when this LED is flashing red. If you do remote data collection with triggering, this LED will flash orange while the WDSS is waiting for a trigger. If there is a problem, this LED will turn steady red. One example of an error condition would be attempting to collect remote data when the WDSS memory is full.
- **Bluetooth Wireless Communication Status LED** This LED indicates whether the WDSS is successfully communicating with a computer, LabQuest[®] 2, or LabQuest[®]. When the WDSS is on, but not connected to any version of Logger *Pro*, this LED appears red. When the WDSS is connected to Logger *Pro*, the Communications Status LED is green.
- **Remote Data Collect Start/Stop button** This button is used to start and stop data collection during remote data collection only. The button is recessed to prevent accidental bumping during field use. You need to press firmly on it. To start remote data collection, press this button. Note that the Data Collection LED will be steady green when the WDSS is ready to begin remote data collection. When you press the Remote Data Collect Start/Stop Button, the Data Collection LED will start flashing. When the WDSS is communicating with a computer and Logger *Pro*, the Start/Stop button is not active.
- **Accelerometer Direction Diagram** The label on the top of the WDSS has a diagram indicating the orientation of the three accelerometers. Note that the x-axis is defined as the long dimension of the WDSS. The acceleration sensing hardware in the WDSS is located directly below the center of this label.
- **Bluetooth Radio antenna (inside the case)** The antenna icon on the label indicates the approximate position of the antenna used for Bluetooth communication. Since radio waves do not pass through metal, avoid putting metal objects over the antenna.

WDSS Power

The WDSS is normally powered by its internal high-capacity Lithium-Ion battery pack. The battery pack is designed to provide power for 20 hours of use. The battery pack should be ready for an hour of use after only about 10 to 15 minutes of charging.



Like all Li-ion batteries, it will undergo a slow self discharge when stored. If you leave it unpowered for many weeks, the rechargeable batteries may lose much of their charge.

You can check the status of the WDSS rechargeable batteries when it is connected to the computer. Click on the icon of the WDSS on the Logger *Pro* toolbar. The WDSS Setup Sensors dialog box allows you to turn sensors on and off and also displays the battery status.

To charge the WDSS Li-ion battery, simply plug in the power supply. The WDSS power supply provides 6 volt DC, 500 mA to a center-negative connector. The power supply is the same one used with the Vernier LabPro interface. The main power switch on the WDSS should be left in the OFF position when charging, unless it is in use. A full charge (from completely dead batteries) should take about eight hours. The Battery Charge LED indicates when the WDSS batteries are being charged. The LED will come on as soon as it is plugged in unless the battery is already 100% charged. The LED will go off when the battery becomes fully charged.

The battery pack and charging system on the WDSS are very flexible. The batteries do not need to be fully discharged before you charge them. Also, you do not need to charge the batteries completely before you use the WDSS.

The WDSS may get slightly warm while charging. When charging it, place it on a surface that is relatively heat resistant. Charge the WDSS only with the power supply that was included with the WDSS or with a LabPro power supply. Do not attempt to charge any other batteries in the WDSS unit.



If you ever need to replace the Li-ion battery and get rid of the original one, please note that it is designed for recycling. In the United States, check the web site www.rbrc.org/ for a list of locations near you where the battery can be recycled. Other countries have similar recycling programs.

Computer Software and Hardware Requirements

The Wireless Dynamics Sensor System must be used with Logger *Pro* version 3.4.5 or newer. The WDSS requires the following computer setup:

Windows: Windows XP, Service Pack 2 or newer is required. For Bluetooth radio you need a Microsoft-compatible Bluetooth radio nub (also called a dongle) or built-in Bluetooth radio that is Microsoft compatible. The Bluetooth radio transmitter must be set up to use the Microsoft Bluetooth drivers. If it has been set up for use with other drivers, the WDSS will not work. You will have to remove those drivers and install the Microsoft drivers. Note that removing other drivers may cause problems if you are using the computer with other Bluetooth devices.

If your computer does not have built-in Bluetooth, we recommend using a Bluetooth radio (dongle) that plugs into the USB port of your computer. If you purchase a Bluetooth dongle for use with this product do not install any software that comes with it. You have to make sure that the adapter has the “Designed for Microsoft® Windows® XP” logo. This identifies hardware that meet or exceed certain quality standards of compatibility with the Microsoft Windows XP operating system.

Macintosh: OS 10.3 or newer operating system is required. Built-in Bluetooth radio or a Bluetooth nub that is Macintosh compatible is also required. Intel processor Macintosh computers (new in 2006) require Logger *Pro* 3.4.6 or newer.

LabQuest 2 or LabQuest Software and Hardware Requirements

WDSS requires a LabQuest running version 1.5 or newer along with a supported Bluetooth radio.

Bluetooth Devices

Bluetooth devices, including the WDSS, connect via radio to the computer. The range of Bluetooth communication is typically about 10 meters. The maximum workable distance between your computer and the WDSS will depend on a number of factors. Any solid object will block some of the waves. Walls and objects containing metal will greatly reduce or totally block the signal. The range also depends on the Bluetooth hardware in your computer.

We will use the following terminology to describe how Bluetooth is used when connecting to the WDSS:

- *Connected* means that a particular computer running Logger *Pro* and the WDSS have established Bluetooth communication.
- *Available* means the WDSS is present, but not connected to any nearby computer.
- *Not Available* means a WDSS is present, but it is connected to another nearby computer. A WDSS that is connected to one computer cannot be seen by other computers.

Vernier Bluetooth devices have been given easy-to-recognize names to help with the setup. They are named using physicists’ names followed by a number. For example, one may be named Newton22.

Connecting your Bluetooth WDSS to LabQuest 2 or LabQuest

1. The LabQuest 2 includes a built-in Bluetooth radio. For the original LabQuest, a supported Bluetooth radio is needed.
2. Turn on the WDSS.
3. Choose WDSS Setup from the Sensors menu in LabQuest App.
4. Tap Scan to look for WDSS devices.
5. Select the desired WDSS by name and tap OK.
6. Select which of the five sensors you want for data collection and tap OK.

Connecting your Bluetooth WDSS to a Computer

To connect the WDSS to your computer and Logger *Pro*, follow these steps:

1. Turn on the WDSS. Note the name on the label of the device.
2. Activate Bluetooth on your computer. Some computers have Bluetooth built in, but not enabled.
3. Start Logger *Pro*.
4. Choose Connect Interface and then Wireless from the Experiment menu. Choose Scan for Wireless Device. There will be a short delay while Logger *Pro* attempts to establish a connection. If the WDSS is not found, try scanning again. A dialog box will appear showing your WDSS on the list of available devices. Choose your WDSS device, and select OK.
5. After the connection is made, the icon of the WDSS and live readouts from its sensors will appear on the Logger *Pro* toolbar. You should have two green LEDs on the WDSS.
6. If your WDSS does not connect, make sure it has battery power and that it is within Bluetooth range. If that does not solve the problem, refer to the *Troubleshooting* section of this manual.

Connecting Your Bluetooth WDSS After Initial Setup (computer)

After you have completed the steps above, and your Bluetooth WDSS is connected to your computer, the connection process can be somewhat simplified. As long as Logger *Pro* is running, it will remember the name of the WDSS devices it has detected. After connecting once, you can simply choose Connect Interface ► Wireless from the Experiment Menu. The name of your WDSS should appear, and you can choose it. You do not need to scan for WDSS devices again.

Active Sensors and the Set Up Sensors Dialog Box

By default, the WDSS will initially report force and three accelerometers. The WDSS has another sensor inside it, the altimeter, which you can activate. Sometimes you may want to turn off some unneeded sensors. Choose Set Up Sensors from the Experiments menu and then select your WDSS device. This will display the WDSS setup dialog that will allow you to turn sensors on or off or change the calibration of the sensors. Experiment files can be saved with any combination of WDSS sensors active and with calibrations specified. When you open one of these experiment files, the appropriate sensor will be made active and calibrated as set in the file.

The WDSS hardware remembers what sensors were last active. If you start it up later, the same sensors will be on by default.



The Set Up Sensors dialog for a WDSS

For each sensor of the WDSS, there is a Configure button offering you options, such as turning on or off the sensor, and selecting calibration options for that sensor. Here is a complete list of sensor configuration options:

For all sensors:

- Calibrate
- Sensor Info
- Zero
- Units

For force only:

- Reverse direction

If you want Logger *Pro* to report data from a particular sensor, turn it on by clicking on its checkbox. If you do not want data reported from the sensor, turn it off. The Calibrate option lets you completely recalibrate a particular sensor. Details of the calibration process are given below. The Zero option simply defines the present reading of the sensor as zero. It is useful for removing offsets from force and accelerometer readings. The Units selection allows you to change the units used by the sensor. For example, you can change from metric to English. The Sensor Info choice provides information on the sensor and how it is calibrated.

The WDSS Setup dialog box also reports other information about the WDSS.

- The WDSS operating system version is displayed and the battery status is listed below that. The battery status is listed as good, low, or very low.
- Manage Memory Button: This button lets you see what remote data is stored in the WDSS, and delete it if you want. It also lists the version number of the WDSS firmware and other information regarding Bluetooth setup.
- Identify button: The Identify button is used to test Bluetooth communication. If you press this button, the Data Collection LED on the WDSS connected to the computer will flash. This is designed as a way to find out which WDSS is connected to a particular computer in a classroom situation with several Wireless Dynamics Sensor Systems.

Live Data Collection via Bluetooth

The active sensor readings are displayed on the toolbar once Logger *Pro* connects with the WDSS. Click on the Logger *Pro* Collect button, and data appear on graphs and data tables. You can use Logger *Pro* as you would with any other interface, such as a LabPro or a Go! Link. To change the data-collection rate or length of the experiment, choose Data Collection from the Experiment menu, or click the “stopwatch” icon on the toolbar.

Calibration and Zeroing

The sensors of the WDSS generally do not need to be calibrated. If you ever want to calibrate them, you can. Details are explained in the Force Sensor, Accelerometers, and Altimeter sections below. For the force and accelerometer sensors, it is often helpful to zero the sensor before data collection. You do this by choosing Zero from the Experiment menu or clicking the Zero button on the toolbar. Make sure the sensor is set up in a zero force or zero acceleration situation before zeroing it. The zeroing operation subtracts any reading at the time from all future readings. It will correct for the tilt of the WDSS or for extra weight pulling on the force sensor (similar to tarring or zeroing a balance).

The WDSS has internal flash memory that stores the calibration of each of the sensors. This allows us to custom calibrate the sensors and it means that if you ever choose to calibrate a WDSS sensor, you can store that calibration in the WDSS memory for use in the future.

Remote Data Collection (Computer only)

The WDSS can also be used to take data remotely, far beyond the Bluetooth range of the computer. Sensor readings are stored in the memory of the WDSS. This kind of data collection is great for amusement park rides, bungee jumps, and sky dives, as well as many less extreme situations. The accelerometers record data while the altimeter of the WDSS provides information on the motion such as a profile of an amusement park ride.

The WDSS can store about 240,000 individual data points internally. This allows for many minutes of data collection. You can repeat data collection several times before retrieving the data from the WDSS. The exact time limit depends on the number of sensors that are active and the data collection rate.

The actual rules for determining the maximum number of readings are complex. Some of the complexity comes from the fact that the WDSS has two kinds of memory: temporary memory (RAM) and non-volatile memory (flash RAM). Data are moved from RAM to flash RAM during or after data collection. Here are some rough rules on how many points you can collect.

- You can store any one run of about 120,000 total readings, counting each active sensor reading separately. This means that if you are using three axes of acceleration measurements, you can take a maximum of about 40,000 readings per sensor.
- If you are reading the three accelerometers and the altimeter, you can take about 30,000 readings per sensor on one run.
- If you use the force sensor for remote readings, it counts as two sensors (this is because inside the WDSS, we treat it as two sensors).
- You can always make multiple remote runs until you fill up the 240,000 point limit, or until you have made 20 remote runs. Even if you set up to collect the full 120,000 readings, you can do that remote run twice and store all that data on the WDSS.
- If you take runs with fewer readings you can repeat many remote runs.

Here is one example: Taking 15,000 readings with four sensors (not using the force sensor) is about 60,000 data points, and thus you can do it four times before retrieving data from the WDSS.

A typical remote data collection run with the WDSS is done with these steps:

1. With the WDSS communicating with the computer (live readouts displaying on the toolbar), set up the data collection. Activate the sensors you want to use. Use the Data Collection dialog to adjust the length of the experiment, the data collection rate, and triggering condition to match what you want to be done remotely.
2. Choose Remote Setup from the Experiment menu, and then choose your WDSS. This dialog box lets you confirm the experimental setup. If you want to check how much memory is available in the WDSS, choose Examine Memory. It lists the number of data points that are available in WDSS memory and lets you delete data, if necessary. Choose OK when you are ready to exit this dialog box and use the WDSS for remote data collection.
3. The WDSS disconnects from the computer and the WDSS data no longer appears on the Logger *Pro* toolbar. The Bluetooth connection LED on the WDSS will turn steady red, indicating that the WDSS is no longer communicating with the computer.
4. To start the remote data collection, press the Remote Data Collection Start/Stop button on the WDSS. Note that the button is slightly recessed to prevent accidental pressing. You need to press carefully to make sure you start the data collection run. The Data Collection LED will change from steady green to flashing green as data collection begins. (If you have set a triggering condition, it will flash orange.) If there is a problem, the Data Collection LED will turn steady red. This probably means that the WDSS data storage memory is full. See Troubleshooting for other possibilities.

Once you have started remote data collection, it will continue until either:

- The time you specified for the experiment has elapsed.
- You press the Remote Data Collection Start/Stop Button again.

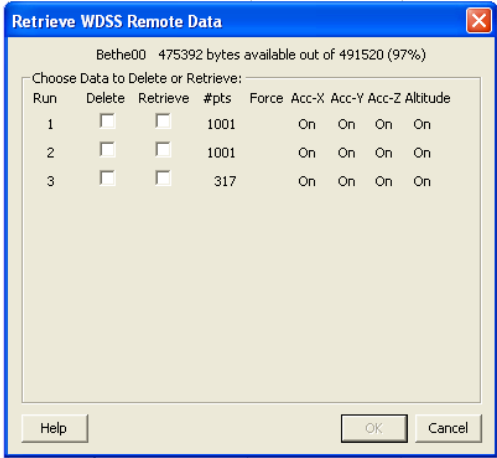
When remote data collection ends, the Data Collection LED will flash red and then turn steady green, indicating data are stored in the WDSS. During the time that the Data Collection LED is flashing red, data are being moved around in the memory of the WDSS, and you should not turn the WDSS off.

Usually after a remote data collection run, the Data Collection LED turns steady green. This means that you can repeat a remote data collection run. You can repeat this as often as you like (up to 20 runs), until you fill the memory of the WDSS. For example, if you are at an amusement park and you have set up for remote data collection on a particular ride, you can have several students take the ride, one after another, pressing the Start/Stop Button on the WDSS each time before reconnecting the WDSS to a computer to retrieve the data.

If the Data Collection LED turns steady red at the end of a run, the WDSS memory is full, and you cannot take another remote run. Full does not mean all memory is used, it means that there is not enough memory for the complete run.

Remote Data Retrieval

To retrieve the data with the computer, move the WDSS into Bluetooth range of the computer and reconnect with it. You can do this by choosing Experiment►Connect Interface►Wireless or you can choose Remote►Retrieve Remote Data and then the name of your WDSS device from the Experiment menu. Either way, *Logger Pro* will notice that the WDSS has remote data, and you will be asked if you want to retrieve it. If you choose No, the data will be left on the WDSS, and you can retrieve or delete them later. If you choose Yes, you are given the choice of retrieving the data into the current file or into a different file. When the Remote Data Retrieval dialog is displayed, it lists all data runs on the WDSS. You can check which ones you want to retrieve and which ones you want to delete. You can retrieve data without deleting it, so that the data could be retrieved to several different computers. One example of this would be when a whole class of students wants to retrieve roller coaster data for analysis on several computers. Delete runs you do not need to use again to free up WDSS memory.



Retrieve WDSS Remote Data dialog box

Triggering

Triggering is possible both in remote data collection and with live data collection.

Triggered data collection will begin when specified trigger conditions are met. Triggered data collection with the WDSS is handled the same as it with the Vernier LabPro or other interfaces. The most common example is in studying collisions. Typically the experimenter wants to take data quickly but only for the interesting part of the experiment—the time near the collision. You can do this by setting up

triggered data collection to start when the force exceeds a certain limit. In a similar way, an acceleration reading can be used for triggering.

Set up triggering using *Logger Pro*. Select Data Collection from the Experiment menu or click the Stopwatch icon on the toolbar, then click on the Triggering tab. Check the Triggering Box at the top left, and then check the On Sensor Value box. Select the sensor to be used and the condition for triggering. For example, you could choose to trigger on the WDSS force reading, when the force increases across 1 newton.

You may also set the number of points to be collected before the trigger condition is met. This is called *Pre-trigger data*. Data will be collected in a buffer and the proper number of points will be saved before the triggering event. This is great for studying the time just before (and making sure you do not miss) a collision. Note that when you request a large number of pre-trigger data points, you will have to wait until those points are collected before the trigger condition can be met.

If you do remote data collection with a trigger condition, pressing the Start/Stop button on the WDSS will cause the Data Collection LED to start flashing orange. When the trigger condition is met, the Data Collection LED will change to flashing green.

The Force Sensor of the WDSS

The WDSS includes a general-purpose load cell for measuring pushing and pulling forces. It can be used as a replacement for a hand-held spring scale, mounted on a dynamics cart to study collisions, or on a ring stand. Many of the experiments that can be done with the WDSS force sensor are explained later in this manual.

Forces as small as 0.01 N and as large as 50 N can be measured by the WDSS. There are actually two force sensing systems inside the WDSS. One is for smaller forces and the other is for forces over 10 newtons. The sensor automatically switches ranges depending on the forces applied. To a user, it seems that as if there is only one force sensor.

How the Force Sensor Works

The WDSS uses a dual-beam aluminum *load cell*. A load cell is an electro-mechanical device with strain gages in a Wheatstone bridge configuration used to convert a force into a differential electrical signal. The load cell provides very accurate measurements of the force with little movement of the force sensor arm. It has good dynamic response and minimal “ringing” (vibration back and forth) when the force is taken away.

As mentioned above, the WDSS force sensor actually reports force in two different ranges, ± 10 N and ± 50 N. If the force is between ± 10 N, then Logger *Pro* will read in the force data from the more sensitive, ± 10 N channel. If the force is outside the range of ± 10 N, then Logger *Pro* will read the force data from the less sensitive, ± 50 N channel. This transition between ranges should not be noticeable.

The load cell is built with internal stops to reduce, but not eliminate, the possibility of damage from excessive force being applied. Do not apply more than 75 newtons (17 pounds) of push or pull to the force sensor. If you do, you may permanently damage the sensor. You may need to re-zero the force sensor if a force greater than 50 newtons is applied to it.

Using the Force Sensor

Start Logger *Pro* software and make sure the WDSS is connected. Normally the force sensor of the WDSS will be on and you will see force readings displayed on the toolbar of Logger *Pro*. If the force sensor is off, click on the WDSS icon at the left of the toolbar and turn on the force sensor.

Hooks or Bumpers

The end of the WDSS farthest from the On/Off switch has an aluminum extension with a threaded hole. This is the connection to the force sensor, and it can be used for mounting various bumpers and hooks for force measurement. It has a standard (US) #6-32 threaded hole. All hooks and bumpers that thread into the Vernier Dual-Range Force Sensor (DFS-BTA) will work with the WDSS force sensor. The WDSS comes with two different accessories for connection here:

Wire hook with plastic lock nut—The hook is used to measure pulling forces (or pushes).



The hook connected to the force sensor

Rubber bumper with 1/2" 6-32 aluminum extension—The Bumper is used mostly for collision experiments or any time you want to measure pushing forces.



The WDSS on a dynamics track with a bumper

Important: If the aluminum extension on the force sensor ever comes out, do not thread anything directly into the #6-32 hole in the load cell that could extend farther than 0.5 cm (3/16 inch) into the load cell. This could damage the load cell hardware.

Force Sensor Calibration

The calibration stored on the WDSS is usually adequate for most force measurements. You usually do not need to perform a new calibration when using the force sensor.

If you want to improve force readings, there are two steps you can take. The quickest and easiest step is *zeroing* the force sensor. This means defining a certain orientation and condition as zero force and subtracting that amount from all future readings. In most cases zeroing is all you need to do before force sensor experiments. It adjusts for any minor offset in the force readings. It also adjusts for the orientation of the WDSS. The sensor is sensitive enough to measure the weight of its hook or bumper. This means that the force reading will change, depending on the orientation of the WDSS. To minimize this effect, simply place the sensor in the orientation in which it will be used (horizontal or vertical) and choose Zero from the Experiment menu or use the Zero icon on the toolbar. This will define the current reading as 0 N of force.

If you want to improve the calibration, it is easy to recalibrate. Simply follow the same procedure that is used in calibrating most Vernier sensors—a two point calibration. The first point should be with no force applied.

1. Orient the WDSS with the hook connected to the force sensor pointed downward.
2. Select Calibrate from the Experiment menu and then select the force sensor.
3. Remove all force from the sensor.
4. Enter **0** as the first known force.
5. Now hang a 1 kilogram mass from the hook on the force sensor.
6. Enter the weight of this mass (9.8 newtons) as the second known force.

We recommend calibrating with a 1 kg mass because of the way the force sensor works. As mentioned above, the WDSS force sensor really is two force measurement systems in one package. One measures forces in the range of ± 10 N range, and the other measures force in the ± 50 N range. The 1 kg (9.8 newton) mass is a good compromise for calibrating both of these force sensors together.

Note that since the calibration process happens in the vertical orientation, if you are going to then take force readings in a horizontal (or other non-vertical) orientation, you should zero the force sensor after calibration, with it held in the proper orientation.

Mounting on a Dynamics Cart

The WDSS was designed for easy mounting on a Vernier or Pasco dynamics cart for force and acceleration experiments.

Mounting on a Vernier Dynamics Cart

For connection to a Vernier Dynamics cart use a $5/8" \times 10\text{-}24$ binding barrel and a hex-head bolt ($1" \times 10\text{-}24$). First place the bolt head in the middle slot of the top of the Vernier dynamics cart. Then lower the WDSS on top of the cart and insert the binding barrel in the large hole of the WDSS. The bolt threads into the binding barrel. Tighten the binding barrel. The process is shown in the series of photos below:



Mounting on a Pasco Dynamics Cart

First insert a $10\text{-}24 \times 1"$ hex head screw through the plastic mounting plate. Next use two $10\text{-}32$ flat head $\times 1/2"$ long screws to mount the plastic mounting plate to the Pasco cart. Finally, use the barrel bolt to hold the WDSS down on the mounting plate. The process is shown in the series of photos below:



Mounting an Extra Mass on Top of the WDSS

For many dynamics cart experiments, it is helpful to be able to add mass to the cart. The WDSS has been designed to allow you to mount one or two Vernier 0.5 kg masses to the cart. These masses are Vernier order code MASS. The photos below show one mass being installed. If a second mass is added, place it next to the first one, toward the force sensor. It is bolted down in the same way.

The hole for bolting down the mass is not symmetrical to the mass. If the mass does not appear to be square to the WDSS, flip the mass over to correct the problem.



Important: Do not use any screw that would intrude more than 8 mm into the threaded hole. This could damage the internal electronics of the WDSS.

Mounting on a Ring Stand

The WDSS is designed to be mounted on a ring stand to allow force measurements in several different ways. Use the rod included with the WDSS (9.5 mm diameter rod, 15 cm long, with a hole in it). Insert a thumb screw through the hole in the rod and into the end of the WDSS nearest the power connector. Tighten the thumb screw.

Another option is to use the aluminum rod threaded into the end of the WDSS nearest the power switch and then attach this rod to a ring stand via a right-angle clamp.



WDSS with thumb screw



WDSS with rod threaded into the end

Hand Held Force Sensor Experiments

The aluminum rod can be used as a convenient handle for holding the WDSS in your hand for some experiments. Avoid large off-axis forces which may damage the WDSS or the rod.

The Accelerometers of the WDSS



The WDSS on a bicycle for studying acceleration

The WDSS has a three-axis -6 to $+6$ g accelerometer inside it. Using *Logger Pro*, you can graph any of these components or calculate the magnitude of the net acceleration. The accelerometer can be used for a wide variety of experiments and demonstrations, both inside and outside the classroom. In the lab, the accelerometers can be used on dynamic carts to study Newton's laws and on rotating objects to study centripetal acceleration. Outside the lab there are lots of possibilities from automobiles to playground equipment to amusement parks. Many examples of acceleration experiments are included in the Experiments section of this manual, below.

How the Accelerometers Work

The Wireless Dynamics System contains a three-axis linear accelerometer with an electronic interface. The accelerometers are fabricated at right angles to each other. Each acceleration sensing unit is micro-machined in silicon with very thin "fingers" carved in silicon. These fingers flex when accelerated. They are arranged like the plates of capacitors. As the fingers flex, the capacitance changes. A circuit on the IC monitors the capacitance and converts it into a voltage signal. The signal is filtered and sent to the analog input of the WDSS. The acceleration reading from each of the three axes is transmitted by Bluetooth to the computer or stored internally during remote data collection.

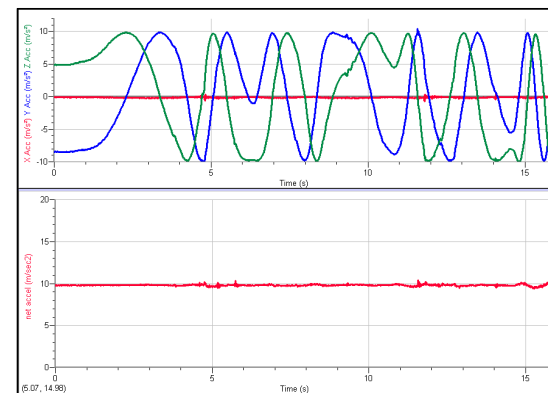
Accelerations are normally measured in either meters per second per second (m/s^2) or g 's. One g is the acceleration due to gravity at the Earth's surface, or 9.8 m/s^2 . This accelerometer will measure accelerations in the range of $-6 g$ (-59 m/s^2) to $+6 g$ ($+59 \text{ m/s}^2$) in each direction. This is a range of accelerations that the human body handles well. Many collisions will produce much larger accelerations. In fact, dropping the WDSS on a hard surface from even a few centimeters can produce accelerations of a hundred g 's. The WDSS accelerometers will not be damaged by accelerations up to 3000 g 's.

The accelerometers are capable of measuring both dynamic acceleration (e.g., vibrations) and static acceleration (e.g., gravity). The three accelerometers are orthogonal with the directions labeled with X, Y, or Z, shown on the label on the top of the WDSS.

To see if your accelerometers are properly calibrated, test their response to gravity. When an axis arrow is held horizontally, that channel should very close to zero. When the arrow representing an axis points upward, that channel should read $+9.8 \text{ m/s}^2$. When an axis arrow points down, that channel should read -9.8 m/s^2 . Note that when the WDSS is in a horizontal orientation, at rest, with the label upward, the x- and y-axes are horizontal and should read near zero. The z-axis accelerometer should read $+9.8 \text{ m/s}^2$. Try it by monitoring the accelerometer readings on the Logger Pro toolbar. You may have to activate some of the accelerometers by clicking on the WDSS icon on the toolbar first.

Logger Pro software can be used to create a “New Column” to calculate the square root of the sum of the squares of the accelerations. This is the magnitude of the net acceleration vector, sometimes called *scalar acceleration*. Many WDSS experiment files have been set up with a calculated column for net acceleration. One example you can open is at Experiment Files/Probes and Sensors/WDSS/Scalar Acceleration. If you want to set it up yourself, choose New Calculated Column from the Data menu. Name the column “Net Acceleration” and define it with the equation $\text{sqrt}(\text{“X-Axis Acceleration”}^2 + \text{“Y-Axis Acceleration”}^2 + \text{“Z-Axis Acceleration”}^2)$. When creating an equation like this, select the Functions and Columns buttons rather than typing in the names and functions.

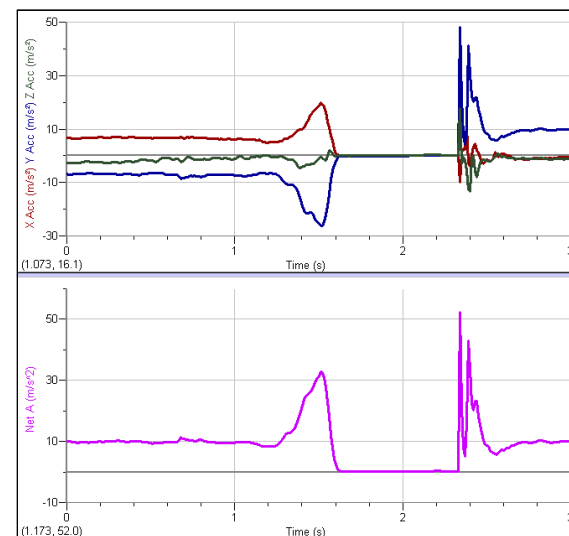
This scalar acceleration, or magnitude of the vector acceleration, is often very useful to monitor and graph. It will be equal to 9.8 m/s^2 when the WDSS has no acceleration and zero when it is in free fall. The orientation of the WDSS does not matter. To understand how this works, try holding the WDSS in your hand and very slowly rotate it about the x-axis as you collect data with Logger Pro. The y and z components of acceleration change drastically. The graphs on the next page show the result. The top graph has all three components of acceleration. The lower graph has the net acceleration (the square root of the sum of the squares of the accelerations). Notice that the net acceleration stays near 9.8 m/s^2 throughout all of this rotation.



Slowly rotating the WDSS and monitoring acceleration

Another way to see how the accelerometers work and how the net acceleration column is useful is to gently toss the WDSS in the air. For safety, first remove the hook or bumper from the force sensor. The most fragile part of the WDSS is the load cell. If you drop the WDSS and it lands on anything attached to the load cell of the force sensor, it may easily be damaged. One good way to protect your WDSS is to tether it with a string attached to the large eyehook in the end. Tie the string so that even if the WDSS is dropped, it cannot fall to the floor.

Below is a graph of the three accelerations with a separate graph of net acceleration. Note that all three acceleration readings and the net acceleration go to near zero during free fall, even though the WDSS unit is changing its orientation as it falls.



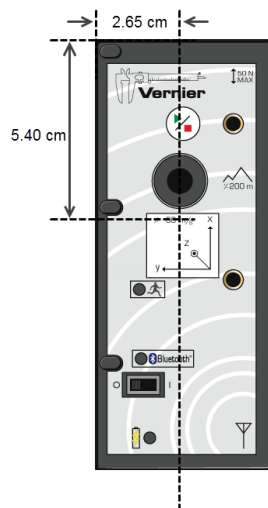
Acceleration components and net acceleration during a toss

The accelerometers are designed to measure small accelerations with minimal signal noise. The noise is typically on the order of 0.1 m/s^2 peak to peak. The calibration will drift somewhat with temperature, but this should not be a problem in most situations.

The use and terminology of accelerometers is a frequent source of confusion for physics students and even instructors. We have added a special section near the end of this manual to try to address some of these issues. Please refer to the *Frequently Asked Questions about Accelerometers* section for more information.

The Exact Location of the Accelerometer in the WDSS

For certain experiments, such as placing the WDSS on a turntable to study centripetal acceleration, it is important to know where the actual acceleration sensing hardware is inside the WDSS. The accelerometer is located approximately below the 50 m/s^2 marking on the accelerometer orientation axis diagram. The sensor is located 54 mm from the force sensor side of the base, 24 mm above the bottom, and on the midline.



Calibrating the Accelerometers

The WDSS accelerometers usually do not need to be calibrated. These sensors are calibrated at Vernier. This calibration is quite good. Since the accelerometers respond to the Earth's gravitational field, you may choose to zero the accelerometers to remove this offset. However, this zeroing is only helpful if the orientation of the WDSS does not change during the experiment. To zero any accelerometer select Zero from the Experiment menu, and then select the sensors you want to zero. You can also just click on the Zero icon on the toolbar.

If you find that zeroing the accelerometer does not adjust the calibration properly, the accelerometer can be calibrated. As mentioned above, accelerometers sense gravity as well as acceleration. This can make interpreting acceleration results more difficult, but it provides an easy calibration method. Since the WDSS has three accelerometers, when you calibrate, you may need to do the procedure three times. To calibrate for the x-axis,

1. Orient the WDSS with the x-axis arrow pointing up for the first calibration point.
2. Define this as $+9.8 \text{ m/s}^2$ or $+1 \text{ g}$.
3. Rotate the WDSS so the arrow for the x-axis points down and use this reading for the second calibration point.
4. Define this as -9.8 m/s^2 or -1 g .

5. The accelerometer will then read 0 with no acceleration when this axis is held horizontally.

6. Repeat this procedure for the other two axes if you want to calibrate them.

Using Just one Accelerometer for Simplicity

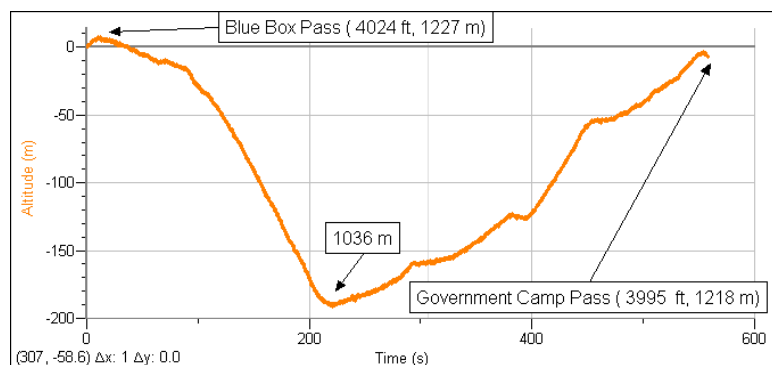
For simplicity, and especially when working with beginning physics students, it is often best to study acceleration along a single axis. Mount the WDSS so that a particular axis is in the direction of the motion you want to study and turn off the other accelerometers. The x, y, and z accelerometer directions are labeled on the top of the WDSS. The following experiments or demonstrations can be done using just one accelerometer: Newton's 2nd law, Newton's 3rd law, acceleration during simple harmonic motion, study acceleration of the human body while jumping vertically, and studying centripetal acceleration.

The Altimeter of the WDSS

The Altimeter of the WDSS measures the air pressure reading and converts it to an altitude. The range of readings is ± 300 meters, or ± 1000 ft. The WDSS reports relative altitude (in meters or feet) and returns that data to the computer. We say “relative altitude” because the altitude setting is defined as zero at the point where the data collection begins. The reason is that you often want to study the change in altitude during the experiment. Examples would include roller coaster rides, sky dives, or bungee jumps. The absolute altitude is not important.

Because air pressure changes very slowly with altitude, the WDSS altimeter is intended to measure altitude changes of 5 meters or more. Smaller altitude changes may not be recorded reliably.

The graph below shows WDSS altimeter data taken in a car while driving in the mountains.



Driving in the mountains with a WDSS reading altitude

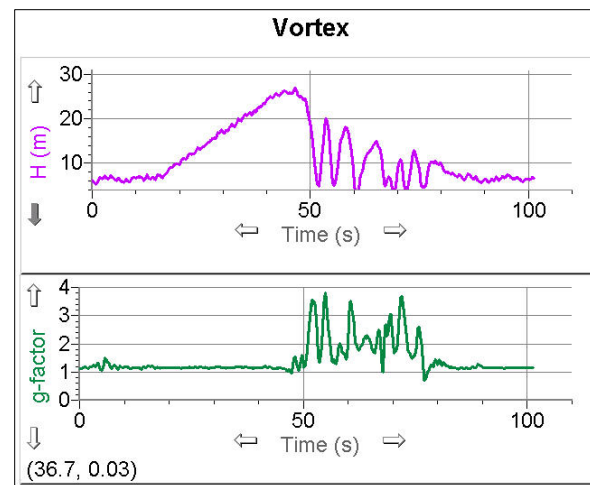
This graph shows that the WDSS reports relative altitude, that is, altitude relative to the start of data collection. In this case, the car was dropping into a valley between two mountain passes, so the altitudes are negative.

If you take the WDSS to a very different altitude, turn its power off and back on one time before collecting remote data. This allows the WDSS electronics to adjust for the large change in air pressure. For example, if you set up the WDSS for remote data collection in your lab at approximately sea level and take it into the mountains for data collection cycle the power off and on before collecting data. Any remote data collection setup will be maintained during this process.

In most situations, the altimeter is used along with other WDSS sensors. A typical use of the altimeter of the WDSS is an amusement park ride. The graphs below show the idea. Notice that the two graphs have identical time axes. The top graph provides a vertical profile of the roller coaster ride. Three accelerometers and an altimeter were used in this experiment. A video taken during data collection can be viewed in

the Sample Movies folder of Logger Pro 3. These data and the associated movie were collected by Clarence Bakken. For more information on data collection in an amusement park visit our web site, www.vernier.com/cmat/datapark.html

Also, you may want to download the *Data Collection at the Amusement Park* manual from the same site.



Data collected on the Vortex

How the Altimeter Works

The WDSS contains a temperature-compensated pressure sensor that is factory calibrated. The sensor is similar to the one in the Vernier Barometer (BAR-BTA). It has a membrane that flexes as the air pressure changes. This sensor is set up for absolute pressure measurement, so one side of the membrane is a vacuum. The sensor produces an output voltage that varies in a linear way with absolute pressure. It includes circuitry to minimize errors caused by changes in temperature. Even so, we are measuring extremely small changes in air pressure and best results will be obtained when the unit is kept at a near constant temperature during data collection. The electronics inside the WDSS translate the pressure reading to an altitude based on the approximation that, for relatively small ranges of altitudes, the pressure varies in a linear way with altitude. (A pressure vs. altitude graph is nearly linear, with a negative slope, over a relatively narrow range of altitudes.) Since the WDSS altimeter always zeros the altitude at the start of data collection, the only calibration factor is the ratio of altitude to pressure (slope of the altitude-pressure graph).

The altimeter will also have a very small response to acceleration because of inertial forces acting on the pressure sensor's diaphragm. If you accelerate the WDSS vigorously, you may notice a very small apparent change in altitude. Similarly, the sensitive pressure sensor may respond to air currents. This effect is also very small.

Calibration of the WDSS altimeter is almost never necessary, but if you choose to do it, it can be handled in one of two ways:

1. Manually change the slope of the calibration equation:
 - a. Click on WDSS icon on the toolbar.
 - b. Click on the Configure button for the altimeter in the WDSS Setup dialog and a pull-down menu is displayed.
 - c. Click on Calibrate.
 - d. Click on the Equation tab of the Sensor Settings Dialog.
 - e. Change the slope of the calibration equation.

or

2. Do a normal two-point calibration, moving the WDSS to two different known altitudes. Since you will probably need to change the altitude more than Bluetooth communications will allow with your computer staying in one spot, this will probably involve moving your computer up and down also. It would work best with a laptop computer.

Experiments Using the Wireless Dynamics Sensor System

Experiments Using Just the Force Sensor

Collision Experiments

Studying forces during collisions of a dynamics cart with a rigid object yields information about how forces vary during collisions. You can vary the bumper or the material between the rigid object and the force sensor bumper. It is a great way to show students that making the collision take more time decreases the peak force. This is an important concept, since it explains a lot of things about automobile safety (air bags, crumple zones, etc.).



Impulse-momentum setup using Vernier Dynamics Track Adapter (DTA-DFS)

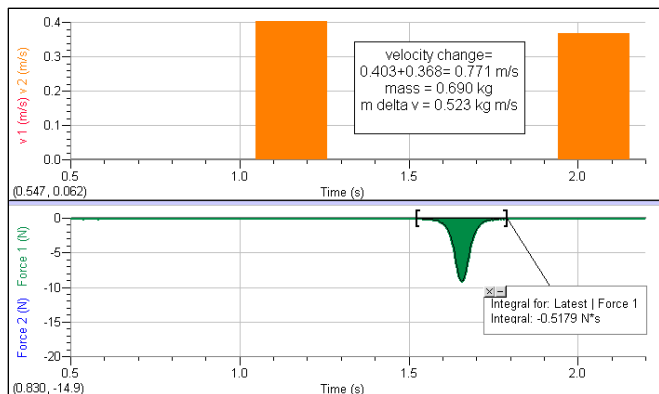
Mount the WDSS on the dynamics cart and have the cart collide with a stationary object at the end of the track. Another option is to screw a vertical rod through the hole in the WDSS and mount the WDSS stationary at the end of the track and have the moving cart collide with it. Collide a dynamics cart into the stationary collision bumper on the WDSS.

A classic experiment is to compare the integral of the force vs. time graph with the change in momentum of the cart undergoing this type of collision. If you get a graph of force vs. time in *Logger Pro*, you can use the Integral tool to do the integration. For studying the momentum change, you need to get the speed before and after the collision. There are three ways to make these measurements:

1. Use *Logger Pro*, a WDSS, a LabPro, and a Motion Detector to make graphs of the motion and the force at the same time. Examine the velocity vs. time graph to determine the speeds before and after the collision.
2. Use *Logger Pro*, a WDSS, and a Go!Motion to make graphs of the motion and the force at the same time. Examine the velocity vs. time graph to determine the speeds before and after the collision.
3. Use a photogate connected to a LabPro, a WDSS, and *Logger Pro* software to measure the speed of the cart before and after the collision. Place an index card

or business card on the cart to act as a “flag” going through the photogate. Logger *Pro* can measure the time it takes the flag to go through the photogate before and after the collision.

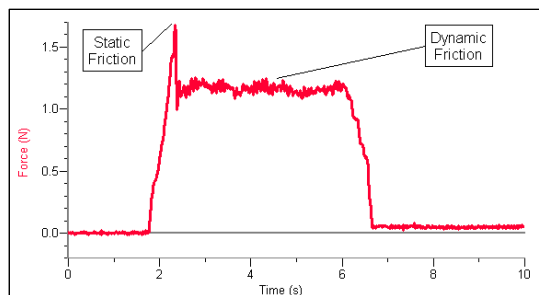
The sample graph below shows the results of colliding a dynamics cart with a WDSS mounted on it with fixed object using magnetic repulsion bumpers. The speeds before and after the collision were measured with a photogate.



Impulse-momentum experiment done with the WDSS

Studying Friction

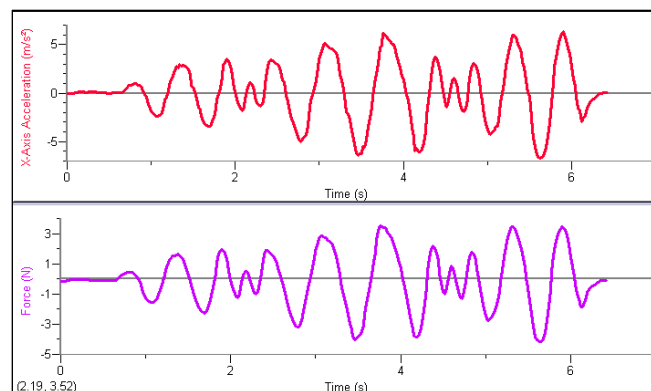
Use the force sensor of the WDSS as a replacement for a spring scale. Run a string from the hook on the WDSS force sensor to a block of wood. Measure the force as you pull the block along a horizontal surface. You can investigate how frictional force is affected by surface area and type of surface. You can also compare static and dynamic friction.



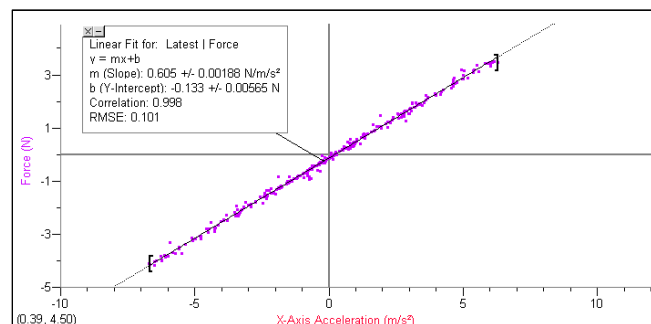
Studying friction with the WDSS

Experiments Using the Force Sensor and Accelerometers

- **Newton's Second Law:** Mount the WDSS on a dynamics cart. Push and pull horizontally on the force sensor hook of the WDSS. Measure the acceleration of the system as the force is varied. This experimental procedure is in the Vernier *Physics with Computers* lab manual. The sample graphs below were made with a WDSS on a Vernier Dynamics cart. The top two graphs are of acceleration and force. The bottom graph is the same data with a graph of force vs. acceleration. Note that the data are nicely linear and has a slope of the $0.605 \text{ newtons/m/s}^2$ or 0.605 kg . This agrees nicely with the measured mass of the cart and WDSS, in this case, 0.614 kg .

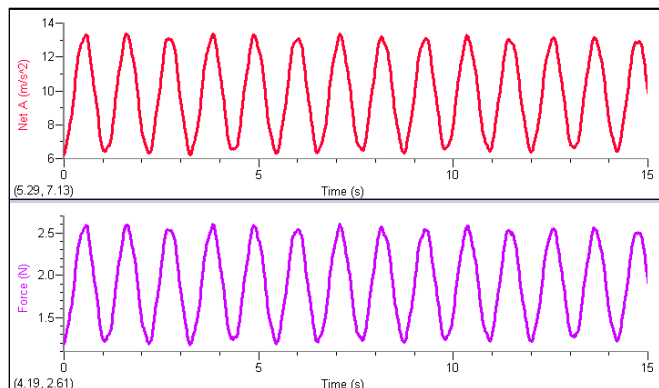


Force and acceleration graphs



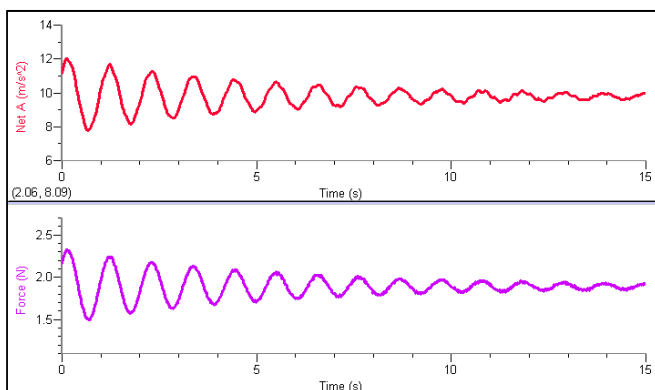
Force vs. acceleration with linear fit

- **Simple Harmonic Motion:** Hang the WDSS from its force sensor at the end of spring so that it undergoes simple harmonic motion. Graph both the force applied and the vertical acceleration. The sample graph below shows the WDSS mounted at the end of a spring and used to study simple harmonic motion.



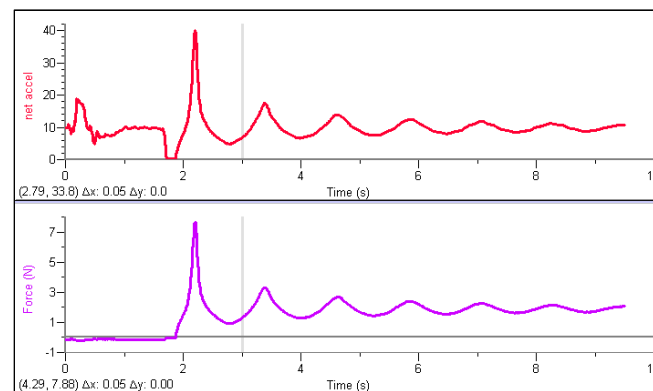
Acceleration and force in simple harmonic motion

- **Damped Harmonic Motion:** Hang the WDSS from its force sensor at the end of rubber band so that it undergoes harmonic motion. The motion will lose energy more quickly and you get a quick change in the amplitude of the motion.



Force and acceleration graphs made with a WDSS suspended by a rubber band (Damped harmonic motion)

- **Pendulum Motion:** Use the WDSS as a pendulum bob, hanging it from the force sensor. Graph both the force on the string and acceleration
- **Model Bungee Jumper:** Connect the WDSS to an elastic cord and drop it so that it moves as a bungee jumper would.

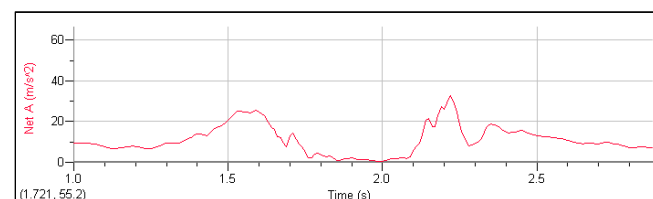


Model bungee jumper data

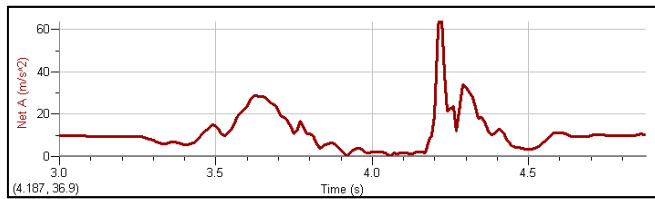
Experiments Using Just the Accelerometers

Some of the best and simplest experiments involve using just one accelerometer at a time. Examples include:

- Measure the acceleration of dynamics carts as they roll down an incline.
- Measure acceleration vs. time on elevators, remote-controlled cars, bicycles, or real automobiles.
- Use the accelerometer to measure the tilt of an object. Since each channel of the accelerometer senses the vertical component of gravity, its reading will change as its orientation is changed from horizontal to vertical. You can measure angles to the nearest few degrees. Create a new calculated column in Logger Pro defined as $\text{tilt} = \arcsin(\text{X-Axis Acceleration} / 9.8)$ or $\text{tilt} = \arctan(\text{X-Axis Acceleration} / \text{Z-Axis Acceleration})$. Be sure to zero the accelerometer carefully. Note that Logger Pro can be set for either degrees or radians as units for angles and trigonometric calculation. Check Settings For... under the File menu.
- Put the WDSS under your belt buckle and jump up and down. Measure the acceleration as you land, both with your knees flexed and with your knees held more stiffly.

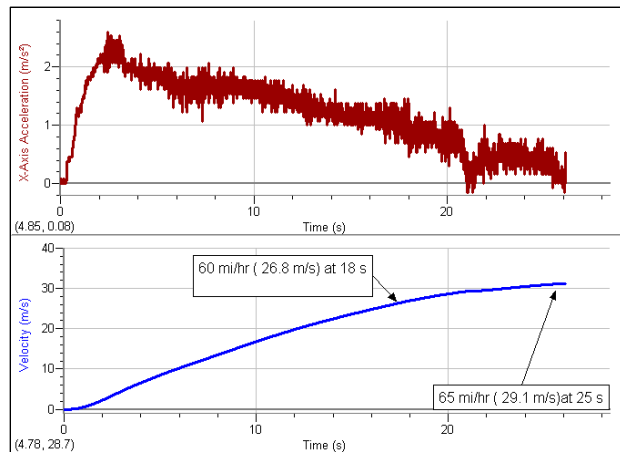


Jump landing with knees flexed



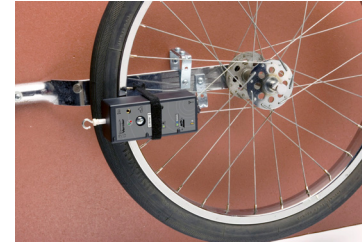
Jump landing with knees held stiff

- Measure the acceleration of a car. The WDSS was placed on the level floor of a car with the x-axis oriented toward the front of the car. The car was started from rest and accelerated to 65 mi/hr (29.1 m/s) while taking WDSS acceleration data. A New Calculated Column was set up in Logger Pro for the integral of the x-axis acceleration. This column is labeled Velocity and plotted on the bottom graph below. By noting the car's speedometer reading at particular times, you can compare with velocities calculated from the acceleration.

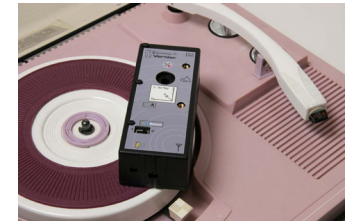


Acceleration of an automatic transmission car

- A single WDSS accelerometer can also be used to study circular motion and centripetal acceleration. Note that you can vary both the angular speed and the radius as you take data.

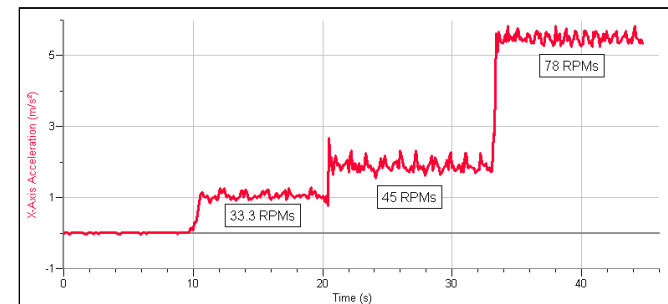


WDSS on a bicycle wheel



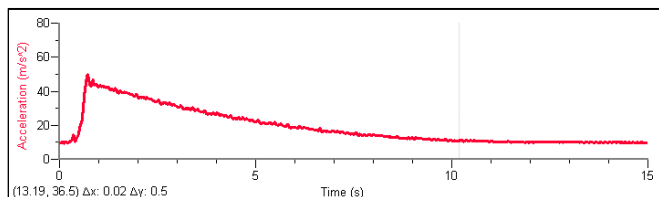
WDSS on a turntable

The graph below shows the centripetal acceleration of a WDSS on a turntable as the angular velocity of the turntable was changed from 33.3 RPM to 45 RPM to 78 RPM.

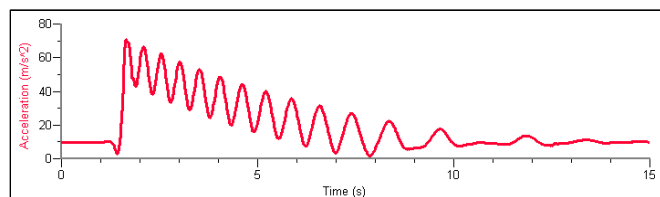


Centripetal acceleration on a turntable

- Mount the WDSS on a free-turning wheel, such as a bicycle wheel. Give it a spin and allow it to slow gradually. Below are graphs made this way with the wheel mounted with its axis vertical and horizontal.



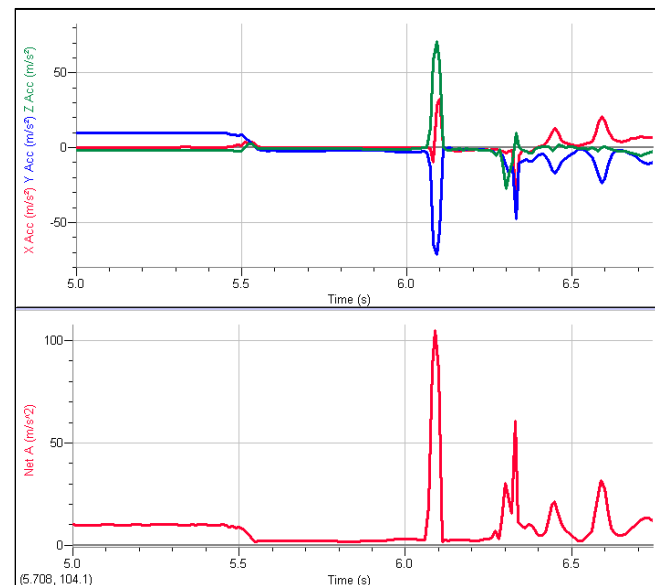
Centripetal acceleration (wheel horizontal)



Centripetal acceleration (wheel vertical)

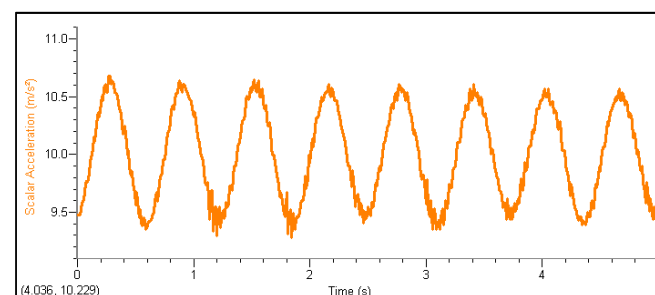
Other experiments require more than one accelerometer to allow you to measure the net acceleration. The easiest way to set this up is to open the file Experiment Files/Probes and Sensors/WDSS/Scalar Acceleration. The alternative is to choose New Calculated Column from the Data Menu to set up a new column that is the square root of the sum of the squares of the accelerometer readings.

- Free fall experiments: Place some packing material (packing peanut, foam, etc.) in a large box. Simply start data collection and drop the WDSS into the box. All three accelerometer readings and the net acceleration drop to near zero during the fall.



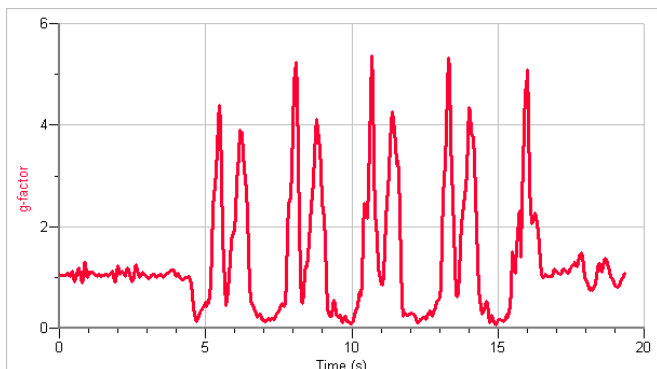
WDSS freefall experiment

- Pendulum experiments: Below is a sample graph made using the WDSS mounted on a pendulum. The pendulum is swinging through a wide angle, so the angle of the accelerometer is changing significantly. A simple, one-dimensional accelerometer would not have done this job as well. In this case, only the net acceleration is graphed. (See the April 1995 issue of *The Physics Teacher* for a discussion of the acceleration of a pendulum.)

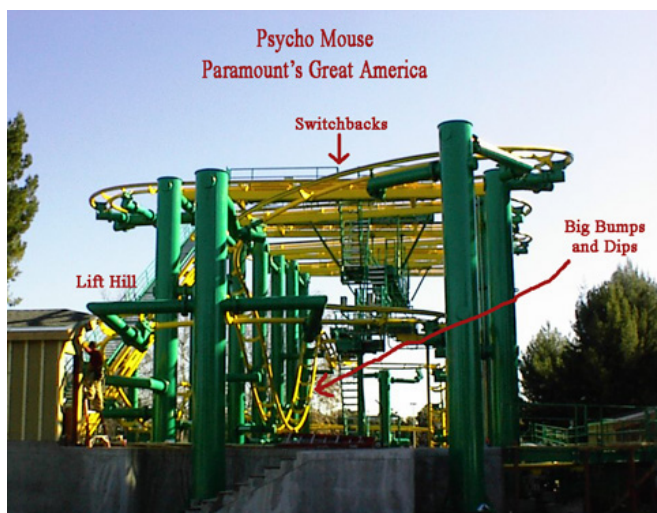


Acceleration of the WDSS used as a pendulum bob

- Experiment with accelerations of skateboarders and dancers by having them perform with the WDSS in their pocket or mounted in a Vernier Data Vest. The graph below shows one example. A movie of the skateboarder taking this data is included in the Sample Movies folder of Logger Pro 3.4.5. It is in the folder Halfpipe.

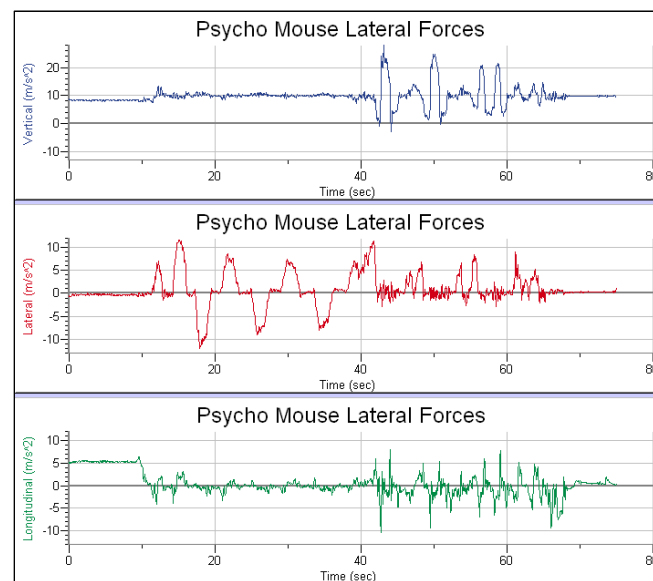


Acceleration on a halfpipe



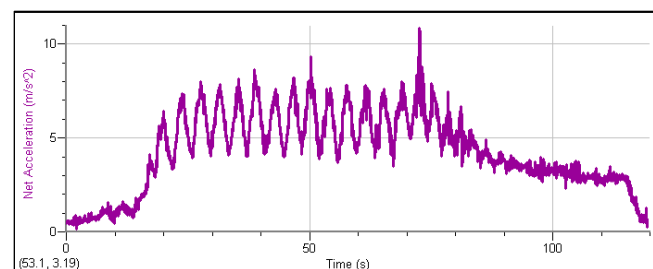
One of the great ways to use the WDSS is on amusement park rides. Here are some examples using just the WDSS accelerometers. Later in this manual, we will have examples where the altimeter is also used.

The following data were collected using a WDSS at Paramount's Great America (CA) ride Psycho Mouse by Clarence Bakken. Remote data collection was used.



Data collected on the Psycho Mouse

Sometimes amusement park data can be collected “live”, that is, with the WDSS communicating with the computer during the data collection. Here is an example. The ride Celebration Swings, at the Paramount Great America park in California, is small enough that during the entire ride the WDSS can be picked up by the computer. Here is the resulting graph.



Celebration Swings data collected live

The same idea can be used for playground rides, skateboarders, dancers and other motions that stay within Bluetooth range of the computer.

Experiments Using the Accelerometers and the Altimeter

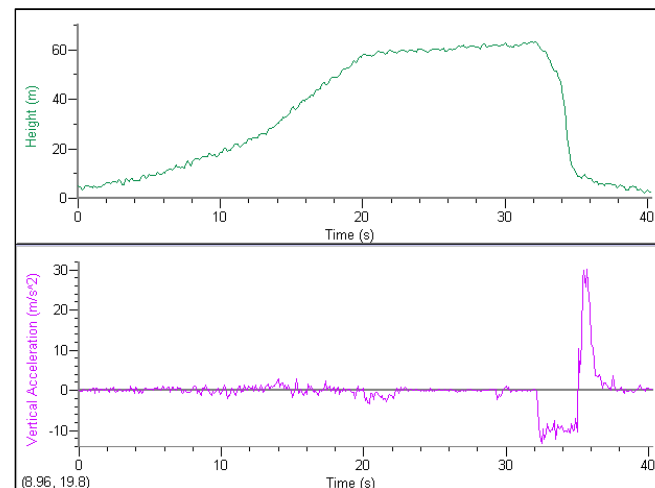
The WDSS was specifically designed for remote data collection at amusement parks and playgrounds. The three accelerometers can record accelerations in all directions and, if needed, Logger *Pro* can calculate the net acceleration. The altimeter of the WDSS can be used to record position on the ride. In general, it does not matter that the altitude be calibrated well; the altitude data provides a profile of the ride, so you can know when the high and low points on the ride occurred.

The WDSS can store over 200,000 data points internally. Using a 25 samples per second collection rate and three accelerometer readings and altitude readings, this allows for a full forty minutes of data collection. You can do multiple runs before retrieving the data.

Set up the WDSS for data collection.

1. With the WDSS connected to your computer and running Logger *Pro*, set up the experiment length, data collection rate, and active sensors. You may want to open a file we have prepared for amusement park ride data collection. It is found in the Experiment Files folder/Probes and Sensors/WDSS, and it is named Amusement Park. It sets up the WDSS to record three axes of acceleration and altitude, and it calculates net acceleration. Data collection rate is set for 25 points per second for 120 seconds
2. To prepare the WDSS for remote data collection choose /Setup/Remote Data Collection from the Experiment menu.
3. Select the WDSS. This gives you a dialog box that displays the data collection parameters so you can confirm that they are set properly.
4. Click OK to set up the WDSS for remote data collection. Note that the Bluetooth connection LED turns red indicating the WDSS is disconnected and ready to start remote data collection.
5. At the start of the ride, press the start data collection button on the WDSS. Note that the Data Collection LED starts blinking green.
6. When the ride ends, press the data collection button again. (If you do not press this button a second time, data collection will continue until the specified time for the experiment has expired or the memory of the WDSS is full).

Many amusement park rides do not require more than one accelerometer. Rides where the motion is in one direction are the easiest for students to understand. Data from the Drop Zone amusement park ride, in California is shown below. This a ride in which the passengers are dropped a distance of about 60 meters and then decelerated by Lenz's Law magnetic forces on the falling cars. They always move in the vertical direction. The lower graph below shows the acceleration. The top graph is an altitude profile of the motion (data taken with an altimeter).



Data from the Drop Zone amusement park ride

WDSS Specifications:

Dimensions: 12.1 cm × 5.3 cm × 3.9 cm

Mass: about 200 g, depending on battery type used and attachments

Batteries: 3.7 volts, 1600–1800 mAh, Li-Ion rechargeable with safety circuit.

Lithium ion batteries self-discharge about 5 to 10% of its stored charge each month until approximately half depleted. This is normal. Disconnecting the battery will not change this.

Operating Current: 35–50 mA @ DC minimum 3.2V

Nominal Charging Current: @ 350 mA

DC input, Rating: DC 6V 500mA maximum

(Max. with battery charging with unit operating)

Bluetooth radio frequency: approximately 2.45 GHz (2450 MHz), with frequency hopping, so the frequency is not fixed

Wireless Range: Up to 10 meters (30 ft) with no obstruction.

Number of WDSS devices that can be connected to one computer: 7

Force Sensor

Range: ±50 N

Frequency Response: 0–100 Hz

Resolution: 0.006 N (< 10 N)

0.03 N (> 10 N)

Accelerometers

(for each of the three accelerometers):

Range: –50 to +50 m/s²

Resolution: 0.04 m/s²

Frequency Response (maximum): 100 Hz

Temperature Range: –40 to +85°C

Altimeter

Altitude change range: ±200 m (1000 ft)

Sensitivity: 1 meter

Combined linearity and hysteresis: typical ±0.1% full scale, maximum ±0.5% full scale

Response time: 0.5 second

WDSS Parts List

The WDSS package comes with the following accessory parts:



AC adapter

Bumper with 1/2" aluminum extender

Small eye hook with plastic lock nut

1/4–20 × 3/4" diameter eye w/ plastic lock nutis

3/8" diameter aluminum rod cross drilled 1/4" at one end

1/4–20 thumb screw (for above)

Mounting plate (for Pasco dynamics cart)

(2) 10–32 × 1/2" flat head screws for above

(2) 10–24 × 1" hex head screw

10–24 × 5/8" binding barrel

Manual (this document)

Troubleshooting:

No LEDs come on when I turn on the WDSS.

- The WDSS rechargeable batteries may be dead. Try charging them.
- The rechargeable battery pack may have been removed from the WDSS. Check this.

When I try to charge the WDSS, the charging LED does not go on.

- The WDSS battery is already fully charged.
- Power is not getting to the power supply. Test the outlet.
- Battery is defective or of the wrong type or missing.

My Wireless Dynamics System does not show when I choose

Experiment►Connect Interface►Wireless►Scan for Wireless Devices

- Repeat the process of trying to connect several times.
- Make sure you are using Logger *Pro* 3.4.5 or newer. Older versions will not work with the WDSS. You can check the version by choosing About Logger *Pro* from the Help menu.
- Make sure your WDSS is fully charged or has good batteries in it.
- Make sure the WDSS is in range for the Bluetooth radio communication. There should not be a metallic barrier between the computer and the WDSS.
- If your computer has built-in Bluetooth, make sure it is turned on.
- If your computer has a removable Bluetooth transceiver, make sure it is plugged in.
- If your computer has a removable Bluetooth transceiver, try removing it and then plugging it in again.
- Try turning the WDSS power switch off and back on and then try reconnecting.
- Try exiting Logger *Pro*, restarting it, and then try reconnecting.
- Try quitting Logger *Pro* and rebooting your computer, then restarting Logger *Pro* and trying again.
- See the specific notes below for Windows and Macintosh users.

My WDSS does not show when I use my Windows computer.

- Make sure you are using Logger *Pro* 3.4.5 or newer. Older versions will not work with the WDSS. You can check the version by choosing About Logger *Pro* from the Help menu.
- Make sure are using Windows XP, Service Pack 2 or a newer operating system. If you have an older version of Windows XP, you must upgrade to SP2.
- If your computer has built-in Bluetooth, make sure Bluetooth is turned on by using the Bluetooth section of the Control Panels.
- Use the Control Panels to try to learn more about your computer's Bluetooth radio. Try to find out if your Bluetooth uses Microsoft drivers. If you have WidCOMM drivers, you need to remove them and install Microsoft Bluetooth drivers.
- If you continue to have problems, check out www.vernier.com/bthelp

My WDSS does not show when I use my Macintosh computer.

- Make sure you are using Logger *Pro* 3.4.5 or newer. If you are using an Intel Macintosh, make sure you are using Logger *Pro* 3.4.6 or newer. Older versions will not work with the WDSS. You can check the version by choosing About Logger *Pro* from the Logger *Pro* menu.
- Make sure are using Mac OS 10.3.9 or newer.
- If your Mac has built-in Bluetooth, make sure Bluetooth is turned on by using the Bluetooth section of the System Preferences.
- If you continue to have problems, check out www.vernier.com/bthelp

The Data Collection LED turns red when while I am trying to collect remote data while taking data with Logger *Pro*:

- The WDSS internal memory is full. There is not enough room to store the run you have set up. Reconnect your WDSS to the computer and delete data from the WDSS memory. You can do this by choosing Experiment►Set Up Sensors►Wireless and then clicking the Examine Memory button.

The Connection LED turns red when I try to start live (connected with the computer) data collection:

- WDSS failed self test. It may have a serious hardware problem. Try turning it off and on. If that fails, contact Vernier Software & Technology.

My acceleration (or force) data seem strange when I am studying a high frequency signal.

- If the frequency of the changes in the force or acceleration signals is higher than your sampling rate, you may well be seeing the results of *aliasing*. The best example of aliasing is seen in movies or television where a car wheel appears to be turning backwards. This happens because the camera only looks at the wheel at certain times and it happens to catch the wheel a bit earlier in its rotation each time around. Another example would be a pendulum where you "sample" just slightly faster than one period. You'd keep seeing it a bit earlier in its cycle making it look like it was moving very slowly in the opposite direction than it is really moving. If you happened to sample it at an interval exactly the same as its period, you could even be tricked into thinking the pendulum bob was standing still. Similar affects can show up when you sample with the WDSS at a rate which is slower than or only a little faster than the frequency of the force or acceleration signal, you may get a confusing result. Try increasing the sampling rate.

There is some strange noise on my acceleration signals.

- Be sure to check to see if the noise is real, perhaps caused by a motor vibration or the wobble of a wheel on a rolling cart. Toy cars with hard wheels on a rough surface can generate great amounts of acceleration noise. Sometimes the noise from surface irregularities is larger than the acceleration being studied. Large, soft wheels are better than small hard wheels and heavier vehicles will tend run more smoothly as well. Fans can be another huge source of acceleration noise (vibration). Sometimes these noise signals can be aliased to show up in unexpected ways.

Frequently Asked Questions about Accelerometers

Q: Why do the accelerometer readings change when I rotate the WDSS?

- A: Since the accelerometers are sensitive to both acceleration and the Earth's gravitational field, interpreting accelerometer measurements is complex. A useful model for understanding accelerometer measurements is a spring-based scale with a reference mass (or object) attached to it. If the scale is pointing upward (the usual orientation for such a device) the weight of the mass causes the spring to compress, and you get a non-zero reading. If you were to turn the scale upside down, the spring will be extended, instead of compressed, and we you would get a reading of the opposite sign. If you turn the scale so it points sideways, and keep it motionless, then the spring will just be at its relaxed length, and the reading will be zero. If you accelerated the scale toward the mass, then the spring would compress. If you accelerated the scale away, and the spring would stretch.

In each case the scale is reading a value corresponding to the normal force on the mass. This reading can be made relative by dividing out the mass, giving units of N/kg, which is the same as m/s^2 .

The accelerometer measurements can be interpreted in exactly this way.

Q: What does a WDSS accelerometer really measure?

- A: It measures normal force per unit mass. Most people prefer that the measurement be in m/s^2 or *g*-factor units that are used in this manual.

Note that it's not the net force per unit mass (which would be acceleration), but it is the normal force per unit mass, where "normal" is in the direction of that particular accelerometer. The normal forces in all three directions make up the sum of all contact forces on the sensor body.

This unusual quantity of normal force per unit mass corresponds with what a rider on a roller coaster feels during the turns. This interpretation is useful even for the scalar total acceleration value, which is 9.8 N/kg for a three-axis accelerometer at rest, zero when in free fall, and greater than 9.8 when making a corner.

This normal force interpretation works even for a one-axis accelerometer being accelerated in a horizontal direction. The reading is non-zero as the device is accelerated, as the test mass inside the device has to have a force applied to accelerate it. That's just a normal force that happens to be horizontal.

When discussing the accelerometer reading, we can call it the Normal Force per Unit Mass, with units of N/kg.

There is an interesting article on acceleration and how one perceives acceleration in the April 2006 *The Physics Teacher*. The article is "Why Do We Feel Weightless in Free Fall?" by Pirooz Mohazzabi.

Q: I thought the accelerometer measured acceleration!

- A: Here we are being very careful to not call something an acceleration when it is not a kinematic acceleration. For example, an "acceleration" of 9.8 m/s^2 for an object that remains at rest is clearly a problematic interpretation, yet that's what the accelerometer reads.

You can correct the accelerometer reading to get a true acceleration by adding the component of the gravitational acceleration field along the direction of the sensor arrow. For example, if the axis of the accelerometer is pointing upward, then the gravitational component is -9.8 m/s^2 . The Accelerometer reads 9.8 m/s^2 when the arrow is upward and the device is at rest. By adding -9.8 m/s^2 , we get zero, which is the correct acceleration. If the arrow is horizontal, then the reading is zero, but the gravitational component is zero, and we still have zero for the true acceleration.

Q: What about g-force measurements?

A: We avoid the term *g*-force because the quantity doesn't have units of force. Instead, *g*-factor can be used as a simplified label for Normal Force per Unit Mass in axis labels and discussions. The *g*-factor is dimensionless. The *g*-factor is then 1 for an object sitting at rest on a table, zero in free fall, etc.

Proper Use

This product is to be used for educational or personal (e.g., hobbyist) purposes only. It is not appropriate for industrial, medical, research, or commercial applications.

FCC Statement

This device is tested to comply with part 15 of the FCC rules.

Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.)

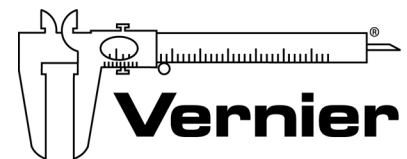
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Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use. The battery is covered by a one-year warranty.



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