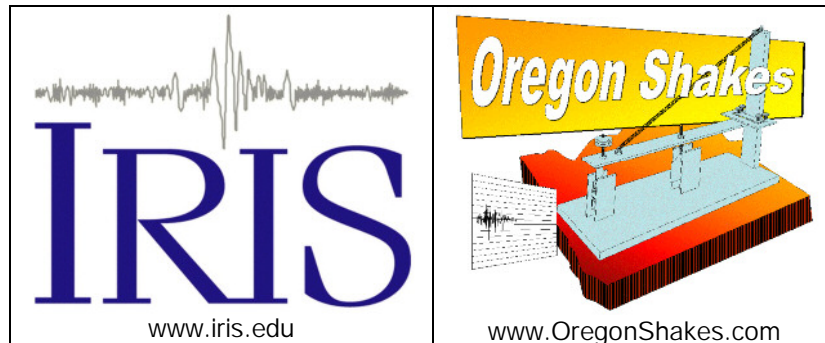


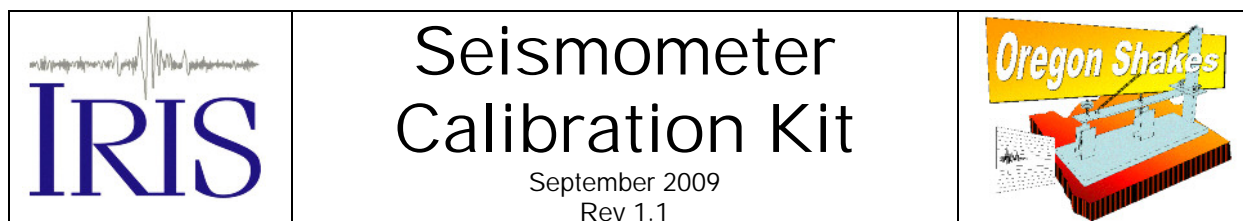
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Seismometer Calibration Kit

September 2009
Rev 1.1

This is the first release of the Seismometer Calibration Kit. We welcome any comments and suggestions regarding this documentation. Please email sishelp@iris.edu to provide your feedback. Thanks!



INTRODUCTION

So, you have just received your seismometer and have performed the initial setup. You are now ready for the important set of calibrating your seismometer. Many of the calibration steps are performed to insure the health of your seismometer. Some of the steps are performed "just in case".

Have you ever been to the doctor and he or she says "let's get an x-ray so we have a good baseline". What the doctor means is that if you have trouble in the future, he can repeat the test and compare it to the "baseline" test. Your seismometer is no different. You want to perform the baseline tests so that if you have problems later it can be used to help troubleshoot your seismometer.

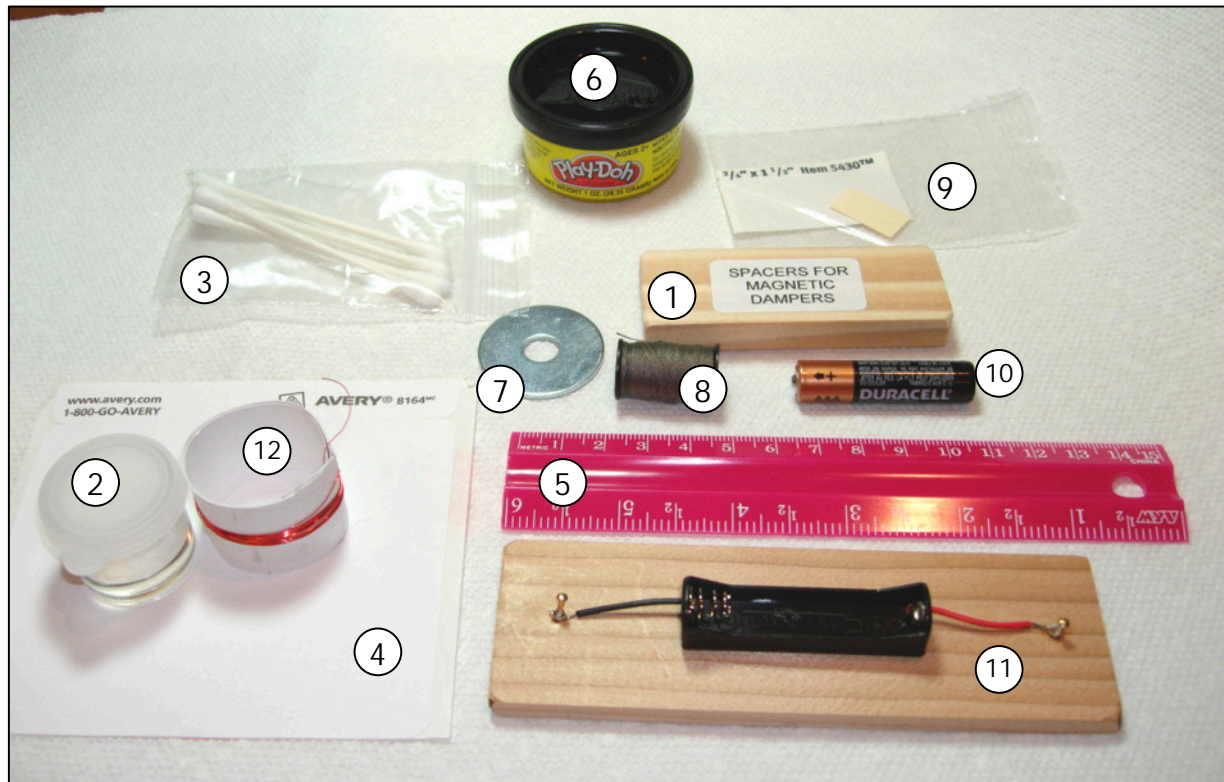
Please note that even if you don't have the seismometer calibration kit, most of the contents are simple household items. So don't let that stop you from using this guide.

So, let's get started!

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WHAT'S IN THE SEISMOMETER CALIBRATION KIT?



1. Spacer to set the spacing between the magnets on the magnetic damper assembly
2. High quality machine oil used for the knife edge tune-up
3. Cotton swabs to apply oil
4. Large sticky label on which to mark location of magnetic assembly
5. Ruler used to calibrate damping
6. Play-Doh used to calibrate damping
7. Washer used for the "washer test"
8. Thread used for the "washer test" and "lift test"
9. Label and paper weight used for the "lift test"
10. AAA battery for the "inductance test"
11. Battery holder for the "inductance test"
12. 32 gauge magnet wire for the "inductance test"

KNIFE EDGE TUNE-UP

On the AS-1, the horizontal boom has a knife edge which fits into a groove on the vertical support. The worst enemy for your seismometer is noise and the knife edge can often be the culprit. The ideal pivot point is friction free. The knife edge will always create a very low amount of noise. But the noise can be quite high if the knife edge gets nicked or is rough. So it is a good idea to occasionally inspect your knife edge, especially after you move it to a new location.

WARNING: The knife edge is sharp so be very careful!



First, remove the boom from the seismometer and detach the spring. Inspect the knife edge. Does it have any obvious nicks or rough spots? If not, skip the sharpening step below. Otherwise proceed to the next step.



The best way to sharpen the knife edge is with a sharpening stone such as the one on the right because the knife edge must be very flat and not have "waves". You may have a friend or neighbor such a stone.



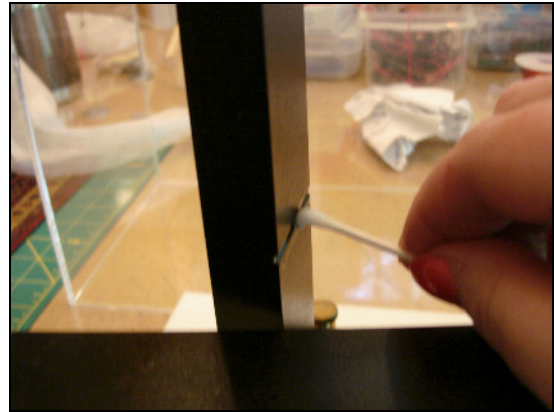
After oiling the stone, hold the boom at about a 20 degree angle and press on the stone while pulling in ONE direction only (towards the end with the magnet). Be sure to sharpen the side with the beveled edge. Once sharpened turn the boom over and make one or two sweeps to remove the "fuzz" or burrs. Carefully wipe the knife edge with a clean dry cloth.



Now remove the lid from the vial of high quality machine oil. Dip a clean cotton swab into the oil.



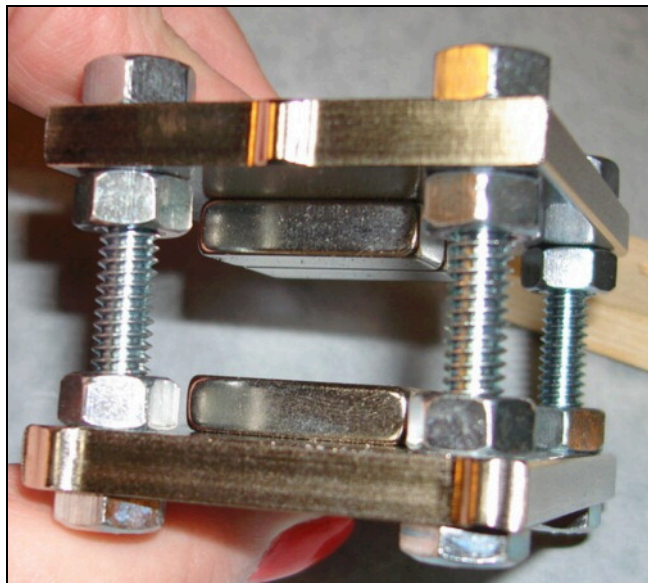
Wipe across the knife edge on both sides. You don't need much oil. A drop or two is sufficient.



Next, with the other end of the cotton swab, dip into the oil and "scrub" the groove on the upright to remove any metal dust or dirt. Wipe dry with a clean dry cloth. You are now ready to reassemble the seismometer!

SET CORRECT SPACING ON THE MAGNETIC DAMPER

If you are using magnetic damping on your seismometer and not oil damping, you have a damper assembly consisting of a copper paddle (attached to the boom) and a quad array of neodymium magnets on two steel plates which sits on the base. Setting the correct distance between the magnets is important for proper damping. But it is also a simple jog to perform. Before you start, please read the safety information below.



SAFETY INFORMATION

These magnets are extremely strong, and must be handled with care to avoid personal injury and damage to the magnets. Fingers and other body parts can get severely pinched between two attracting magnets. Neodymium magnets are brittle shatter if allowed to slam together. Eye protection should be worn when handling these magnets, because shattering magnets can launch pieces at great speeds.

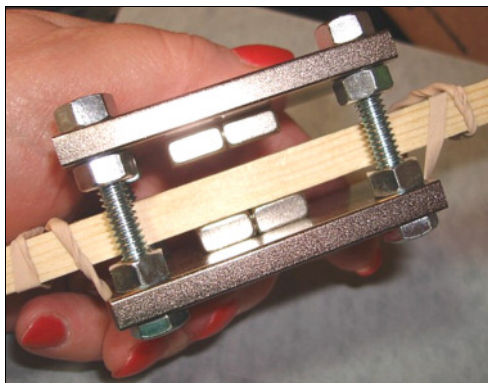
The strong magnetic fields of neodymium magnets can also damage magnetic media such as floppy disks, credit cards, magnetic I.D. cards, cassette tapes, video tapes or other such devices. They can also damage televisions, VCRs, computer monitors and other CRT displays. Never place neodymium magnets near electronic appliances.

Now that we have the safety issues behind us, let's talk about how the device works. The copper paddle extending from the boom is moved between pairs of strong neodymium magnets. The movement of the copper paddle is perpendicular to the magnetic field. This induces "eddy currents" within the paddle which actually create internal magnetic fields opposing the change. This "electrical resistance" within the copper paddle causes a dragging effect analogous to friction, which dissipates the kinetic energy of the paddle. The same technique is used in electromagnetic brakes in

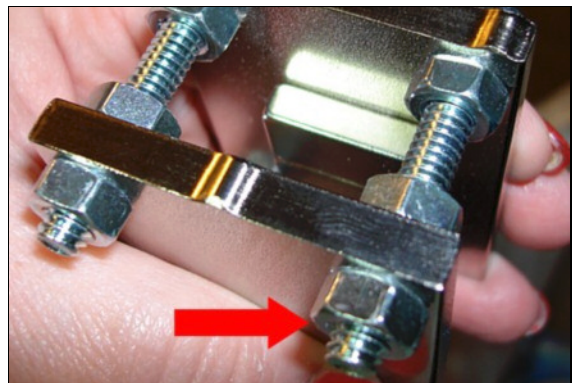
railroad cars, brakes in roller coasters and to quickly stop the blades in power tools such as circular saws.

This effect is insensitive to temperature (although at very high temperatures neodymium magnets lose their strength). That is why it is preferable to oil damping. The properties of the oil damping change dramatically with temperature – not a good thing!

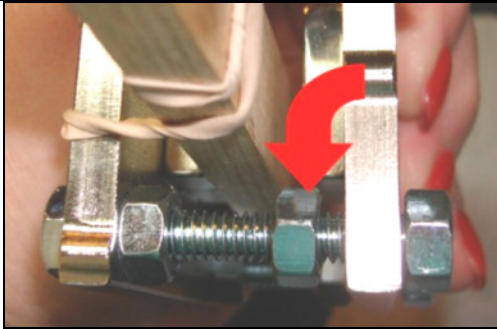
When you receive the magnet assembly it may not be set correctly. The magnets on each side of the steel plates must be set approximately $7/16"$ apart. If you look in your calibration kit you will find a small piece of wood as shown below. It is approximately $7/16"$ thick. You will use this as a guide to set the magnet separation.



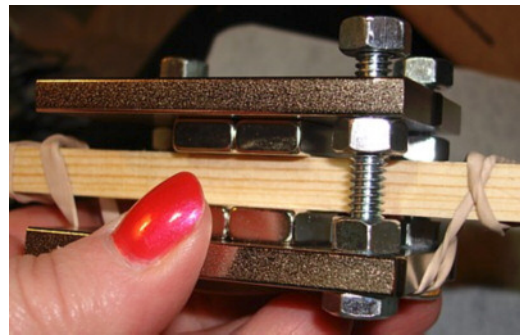
Slip the spacer between the magnets. If it won't slip between the magnets you will need to widen the separation. Otherwise you will need to bring the plates closer together.



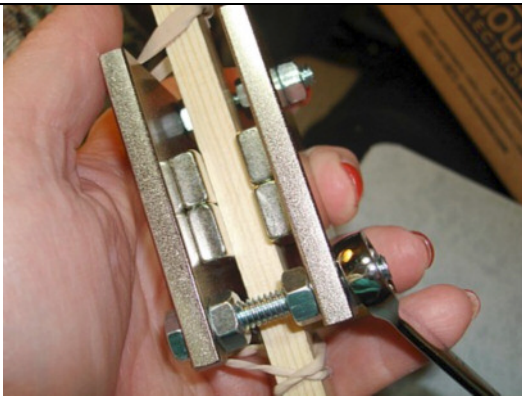
Next, with a $7/16"$ wrench or pliers slightly loosen the nut at the end of the bolt. Be sure to loosen the end nut and not the bolt head.



Then loosen the nuts on the other side of the steel plate. You will adjust these nuts so that the steel plate will drop down to the spacer



The plate should drop down so that the magnets just barely touch the spacer. It needs to be loose enough so the spacer can easily be slipped out of the magnetic assembly.



Finally finger tighten the outside nuts. Then with a wrench or pliers tighten the nuts securely to hold the steel plate in this position.

LEVELING YOUR SEISMOMETER

Make sure that your seismometer is properly leveled. Start by placing the small bubble level between the two thumbscrews near the vertical support of the seismometer.



Adjust the two screws until the bubble is centered in the level.



Now move the bubble level near the coil on the base. Adjust the single thumb screw till the bubble is centered in the level.



Now place washers on the vertical bolt near the magnet end of the boom. Keep adding washers until the boom is almost, but not quite, level. Then place the bubble level on the boom and slide it on the boom till the bubble level shows it is level. Be sure to leave the bubble level on the seismometer.

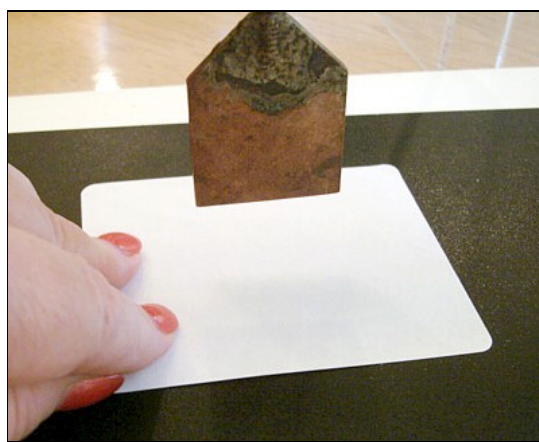
DAMPING CALIBRATION

Magnetic damping is preferable to oil damping because it is not affected by temperature. When the oil in an oil damped system gets cold it can exceed critical damping and you may not record any earthquakes at all. Once set properly, a magnetically damped system will operate properly at all times and hence you may record more earth quakes. The catch is that it must be properly set.

Before you perform the damping calibration, be sure that you set the correct spacing between the steel plates as described in the previous step.



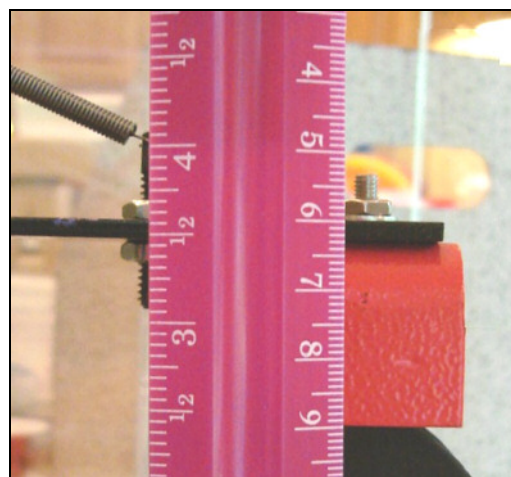
First, clean the seismometer base underneath the damper paddle to remove any oils and dirt. Let it dry completely



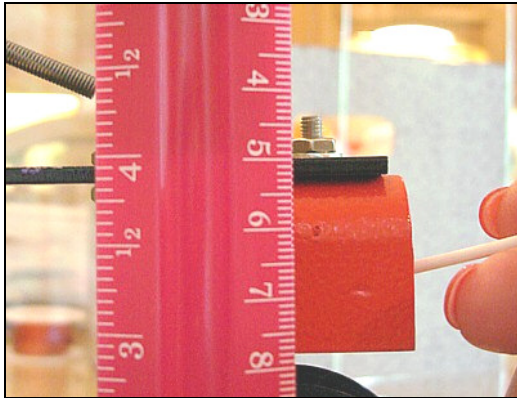
Then place the white sticky label underneath the paddle. It won't stick unless the base is clean and dry.



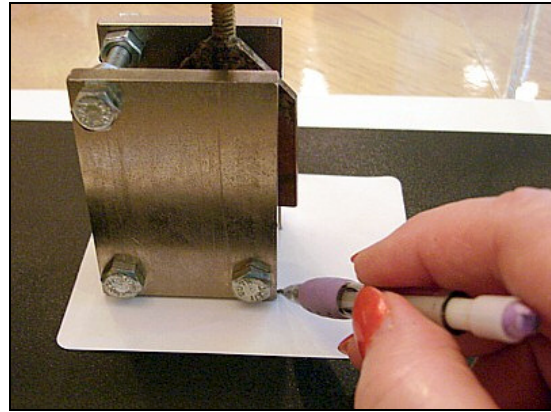
Open the container of clay and set it next to the coil. Push the ruler into the clay with the centimeter scale on the side of the magnet.



Push the ruler in till the top of the boom aligns with a centimeter mark. Here the top of the boom is aligned with 6 centimeters.



Now take a pencil and raise the boom exactly one centimeter. In our example, the top of the boom is now aligned with the 5 centimeter mark. Then quickly remove the pencil and watch closely as the boom drops down. Adjust the position of the magnet block until the boom drops down 0.5mm PAST the resting position. In our case, it dropped down 0.5mm past the 6cm mark to 6.05cm.



Next, mark the position of the magnet block on the white paper label with a pencil. Now, if you move or bump the seismometer you can easily reset it by moving the magnet block to the location you marked!

Sometimes it is difficult to see the 0.5mm overshoot. Some people prop up a magnifying glass in clay to help see the overshoot. With some people their hands may shake making it difficult to hold the boom up exactly 1cm before dropping it. A good trick here is to sharpen a pencil at both ends so that it fits beneath the boom at approximately its resting position. Then a quick flick on the pencil will let the boom drop. There are many ways to do this so choose the method that works best for you.

ALIGNING THE MAGNET/COIL

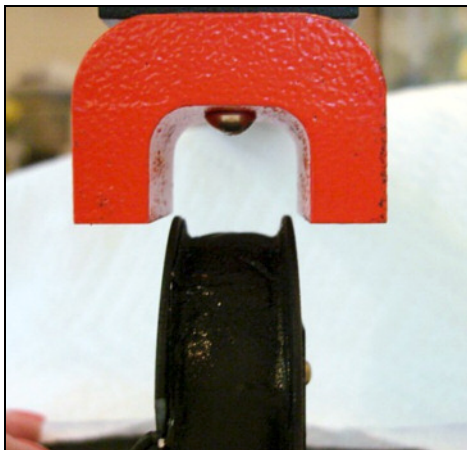
This is an easy calibration. The goal is to keep the magnet from rubbing against the coil. You want to make sure that the boom/magnet moves freely without friction from the coil. By the way, this is one of the most common errors and it is a sure way to miss those earthquakes that you wanted to record.

Be sure that the base and boom are properly leveled before you perform the alignment.

Now, move around the seismometer till you are looking at it end on. Observe the red magnet. Is it centrally spaced over the coil? If the answer is yes, you are good to go!

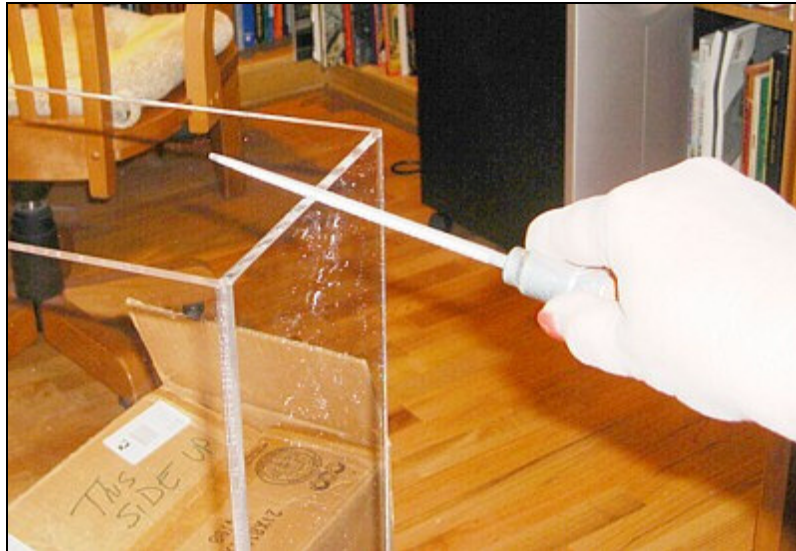
If the answer is no and it is only slightly off, slide the boom back and forth at the knife edge pivot point till it is aligned properly.

If the answer is no and it is off by more than $1/8^{\text{th}}$ of an inch, look at the metal support holding the coil. Is it perpendicular to the base? If not, VERY carefully bend it so that it is vertical. You don't want to bend it too much or too often because the metal can fatigue and break. Once the coil support is vertical do the final adjustment as described in the previous step.

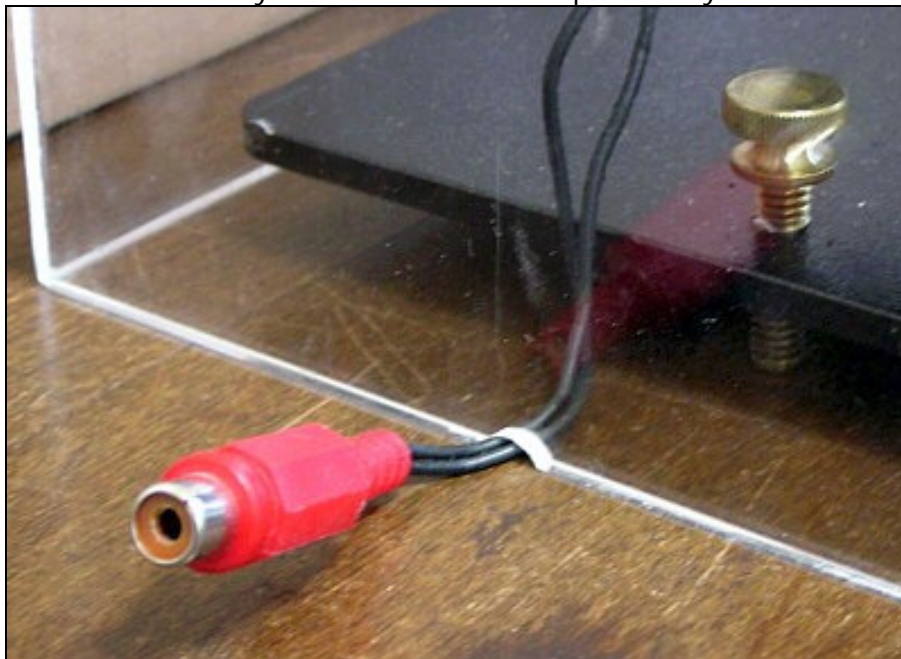


FILING A SLOT IN THE ACRYLIC COVER

It is important to minimize any air currents inside the cover over the seismometer. If the cover rests on the cable then air can seep in underneath the cover. It is best to file a small round slot on the bottom of the cover where the cable can feed out to the "black box". Use a round file to do this. A friend or neighbor may have a file such as this.

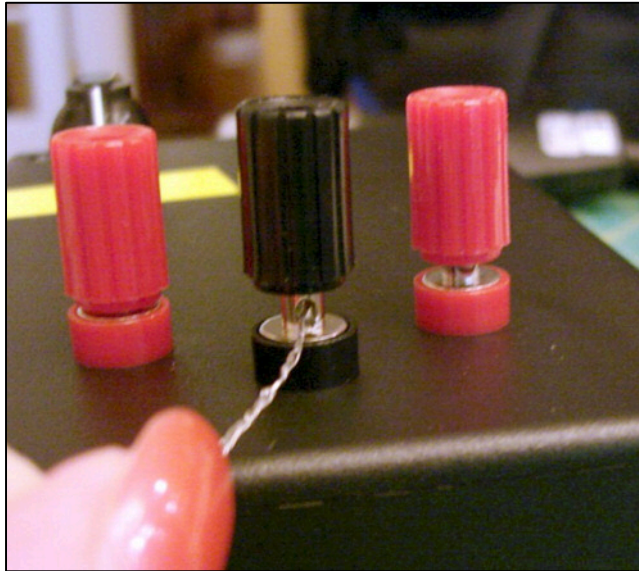


Now the cover will rest directly on the floor or tabletop and very little air can seep in.



CHECKING WIRES TO THE “BLACK BOX”

One of the best ways to introduce noise into your system is by incorrectly feeding the seismometer wires into the “Black Box”. Here are two hints for you to make sure this doesn’t happen to you.



Hint #1

Make sure when you feed the wires into the holes on the screw jacks. Yes, this is obvious, but it is so easy to miss the hole. And, even if you miss the hole you can still clamp it down with the screw cap. But this can easily lead to a loose connection making it very difficult to diagnose the problem.

Hint #2

If you feed too much wire through the hole they may touch each other leading to a short in the connection. This can be intermittent too making it very difficult to diagnose.

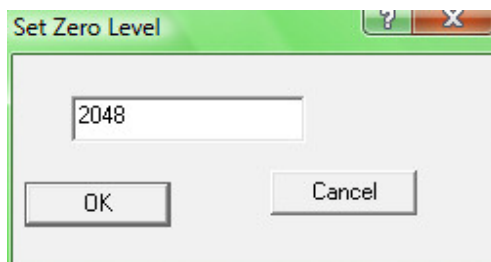


SETTING THE ZERO LEVEL

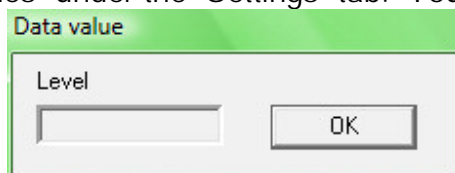
This is the step that strikes fear in even the boldest teacher! Setting the zero level is probably the most difficult part of setting up an AS1 system. The knob on the AS1 "black box" is VERY sensitive.

First make sure that the AmaSeis display show one hour of data per line.

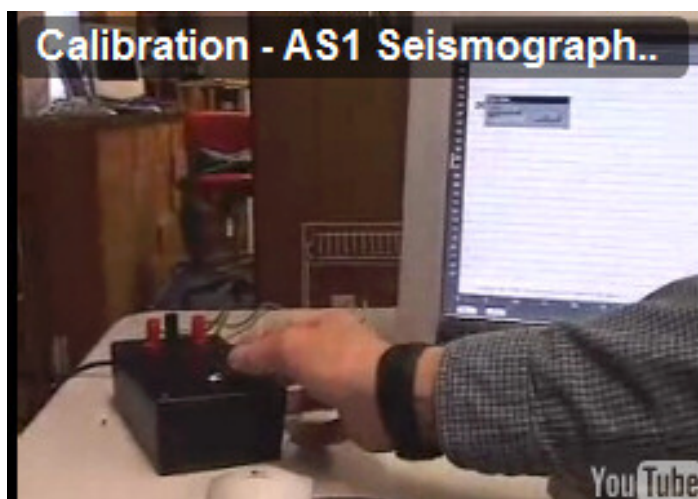
Under the "Settings" tab in AmaSeis click "Set Zero Level". Make sure that it is set to "2048". This is because the "black box" has a 12 bit digital to analog converter and so the numbers will range from 0 to 4096. By setting the "zero level" to 2048, AmaSeis will interpret the input numbers from 0 to 2048 to be -2048 to 0 and the input numbers 2049 to 4096 to be 1 to 2048.



Next click "Show Data Values" under the "Settings" tab. You will see the following:



When you turn the knob all the way to the left the data values will be pegged on either minus or plus 2048. As you turn the knob all the way to the right it will be pegged in the other direction.



Now slowly turn the knob as you watch the level. Once you get it to within about 100 counts of zero (it will fluctuate above and below a few counts depending on the noise

level) you should make slight adjustments by tapping the knob lightly with a pencil until the numbers bounce equally above and below zero.

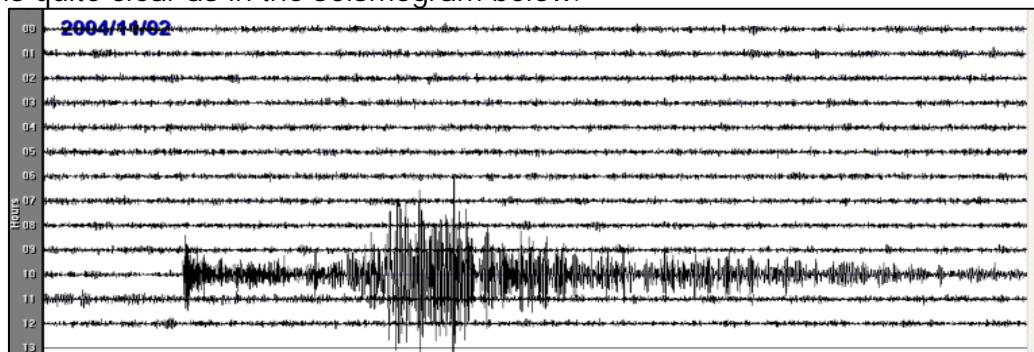
Once it is adjusted it is helpful to put a piece of tape on the "Black Box" and place a mark by the pointer on the black knob.

And to protect the setting on the black box we recommend that you cover the adjusting knob. One way is to cut off a 1" length of the cardboard tube on a paper towel roll. Place it over the knob and then tape it on the black box. Be careful not to change the adjustment while you are taping.

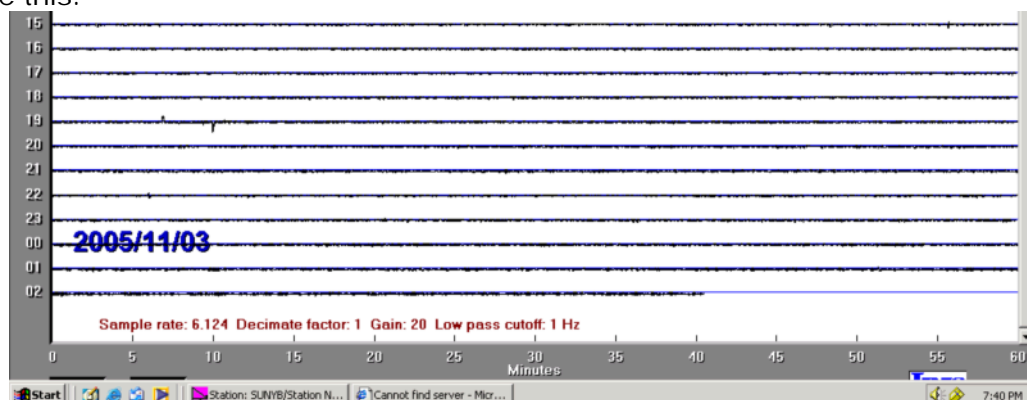


ADJUSTING THE GAIN BASED ON THE BACKGROUND NOISE

In the "Settings/Helicorder/Gain" set the helicorder display gain so that the background noise is quite clear as in the seismogram below.

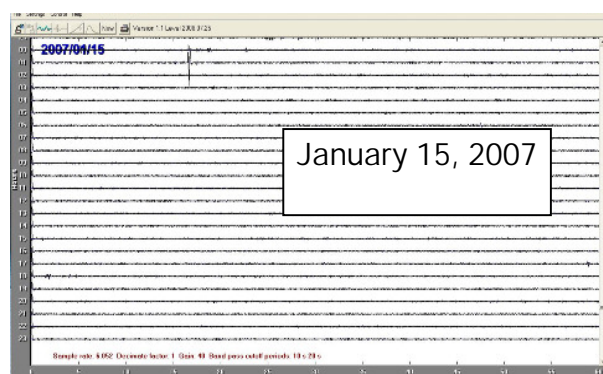


The gain on the record below is too low. You might miss seeing earthquakes when it is set like this.

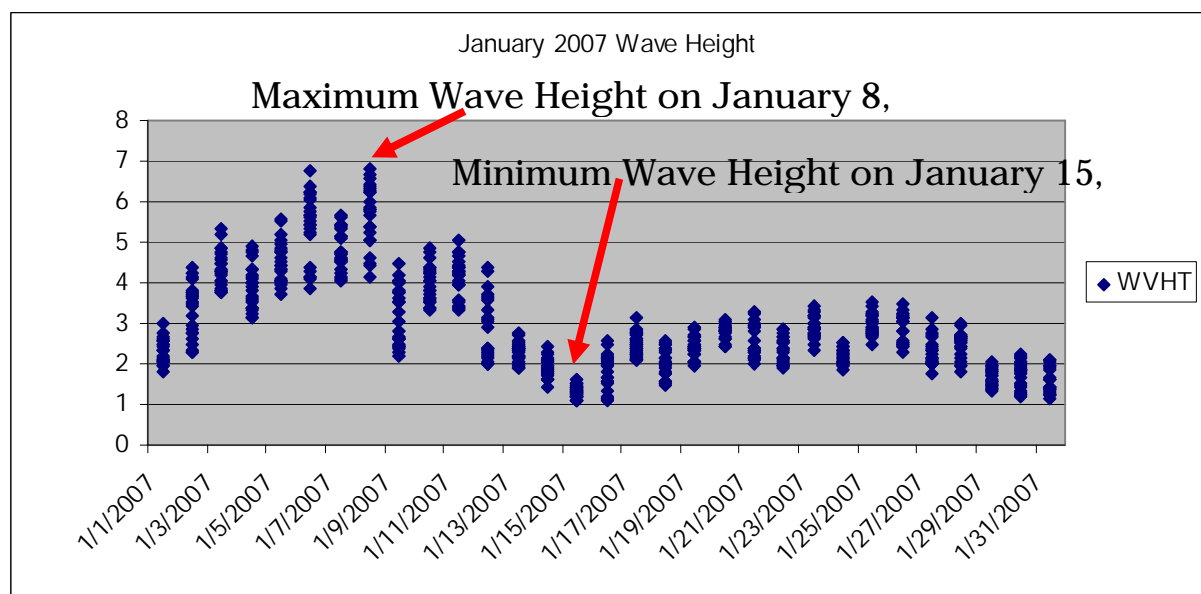
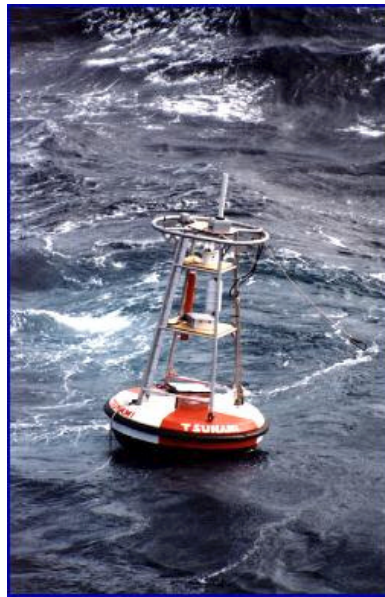


The gain may need to be reduced during storms and increased during quiet times so check it often.

Below are seismograms from a seismograph located near the ocean. The one on the left was from a relatively calm day and the one on the right was from a day when the "surf was up" on the ocean. The gain should have been lowered on the stormy day and the gain should have been raised on the calm day.



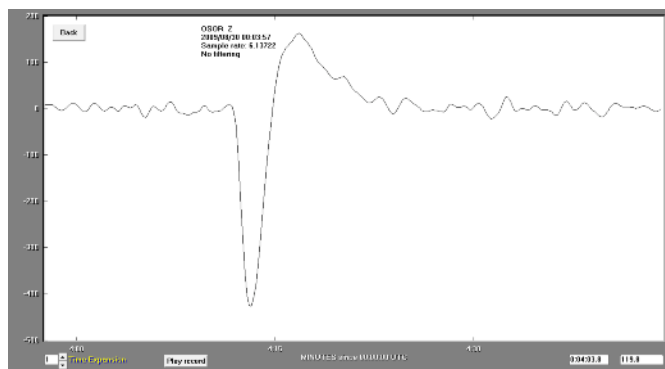
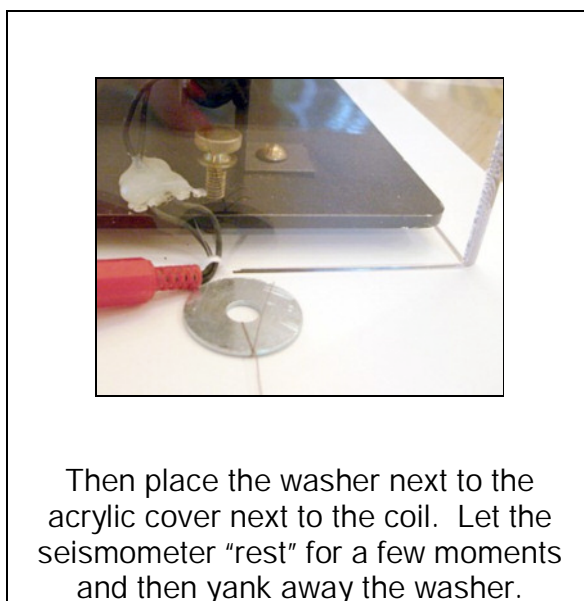
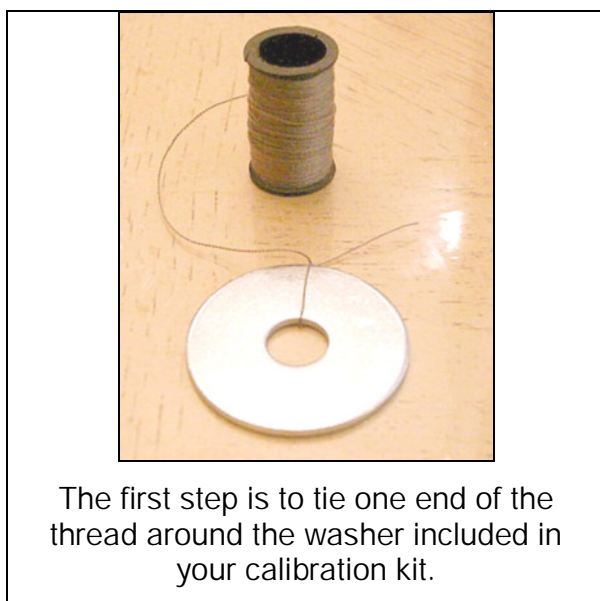
In fact, we can correlate it to wave height using NOAA buoy data below.




WASHER TEST

The washer test is the first test done after the seismometer is connected to the black box. Be sure to first perform the zero level adjustment using the AmaSeis software.

The washer test is the simplest of all the “post hook-up” tests and is helpful for a variety of reasons. It can help to make sure that you have the polarity set correctly. And should you run into problems later on it is simple to repeat the procedure to see what changed (if any) have occurred. And, it can be used to help the IRIS support folks diagnose any problems that may exist.



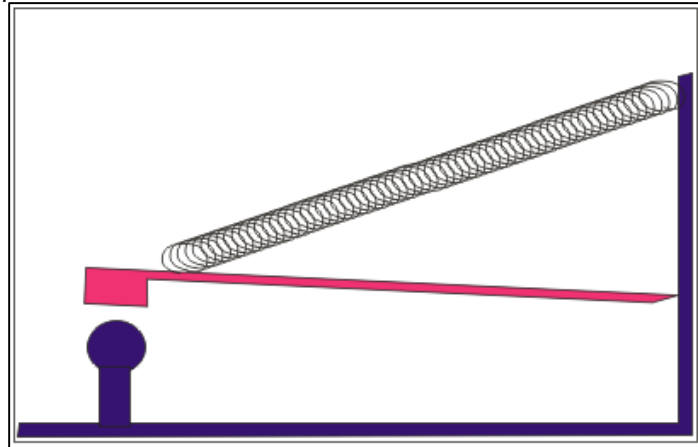
You should see a waveform that looks similar to this. Highlight it with the cursor and then click the AmaSeis

plot icon . The calibration pulse should go down, then up and then return to zero. If the pull first goes UP swap the outside leads into the “Black Box”. Do NOT change the center ground lead into the “Black Box”. You will likely see some level of

microseism noise on the pulse as well. Take a moment to note which way the magnet moved and which way the seismogram trace moved when the washer was pulled away.

Save the calibration pulse as a SAC file for future reference.

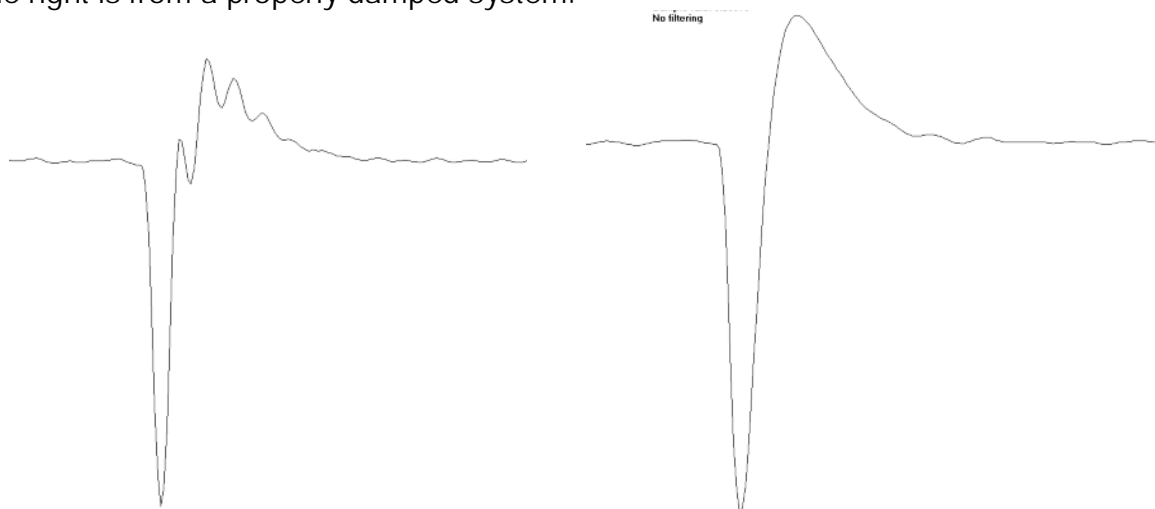
When the ground moves down, the magnet will tend to remain fixed, which means it moves up with respect to the coil.



Note that the overshoot during a washer calibration is primarily due to the electronic filters in the AS-1 "black box".

This overshoot will be much more than 1/20th of the first pulse, as it should be.

However, this test can reveal whether the system is properly damped. Look at the pulse below on the left. This is from a system that had too little damping. The pulse on the right is from a properly damped system.

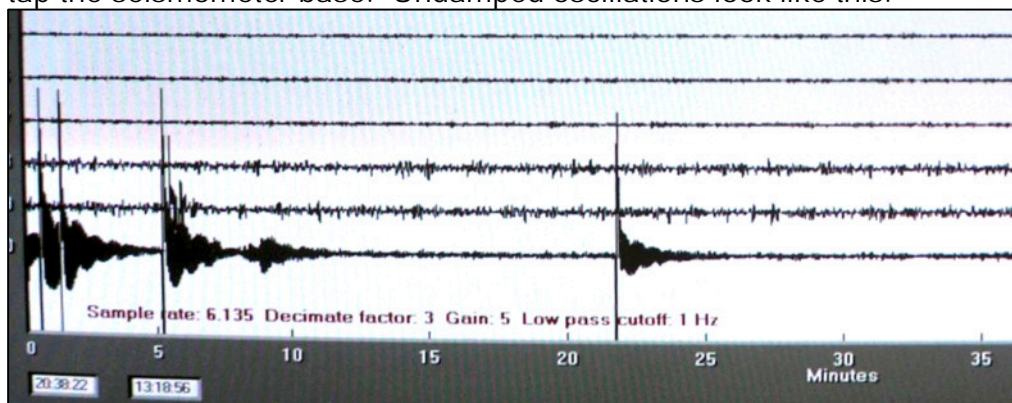


CHECKING THE SYSTEM'S FREE PERIOD

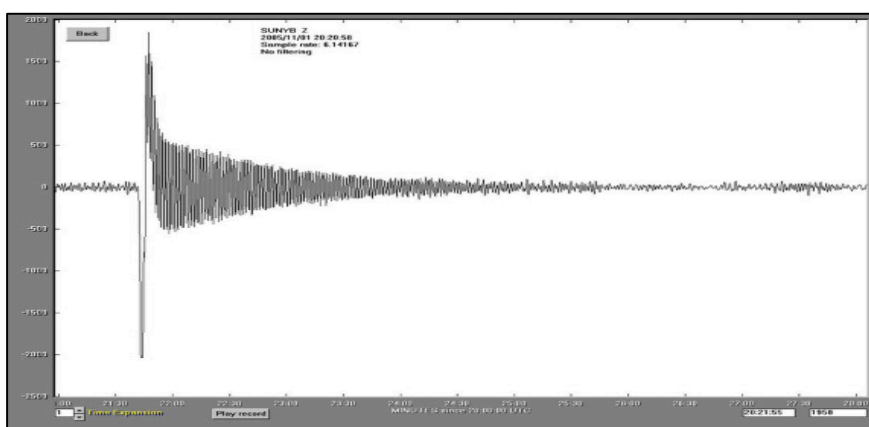
First, pull the magnet carrier away from the copper damping vane.



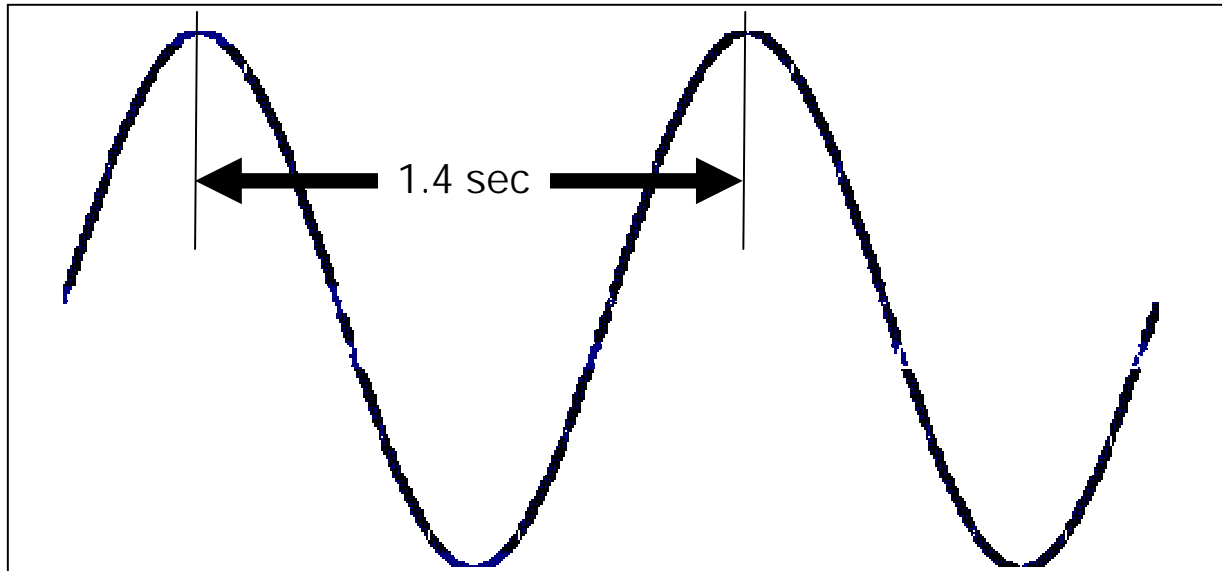
Next, make sure the helicorder setting displays one hour per line and set the gain to 5. Gently tap the seismometer base. Undamped oscillations look like this.



Select one of the pulses and click the icon to display a single trace. The oscillations should continue for at least three minutes. Save a file in SAC format showing the free oscillation decay so that it can be compared with a similar test in the future to determine if the spring or hinge has changed.



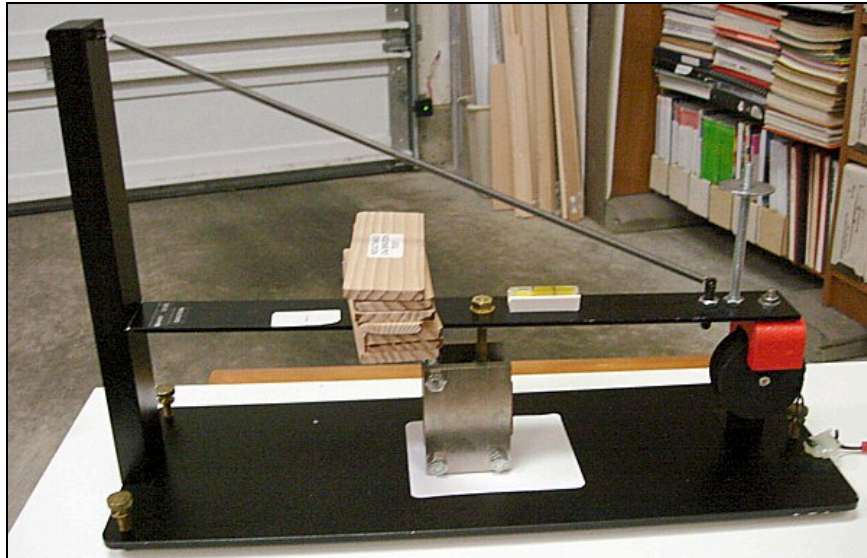
Measure the time between two peaks or two troughs. This is the free or natural period of the system. Here we measured 1.4 seconds.



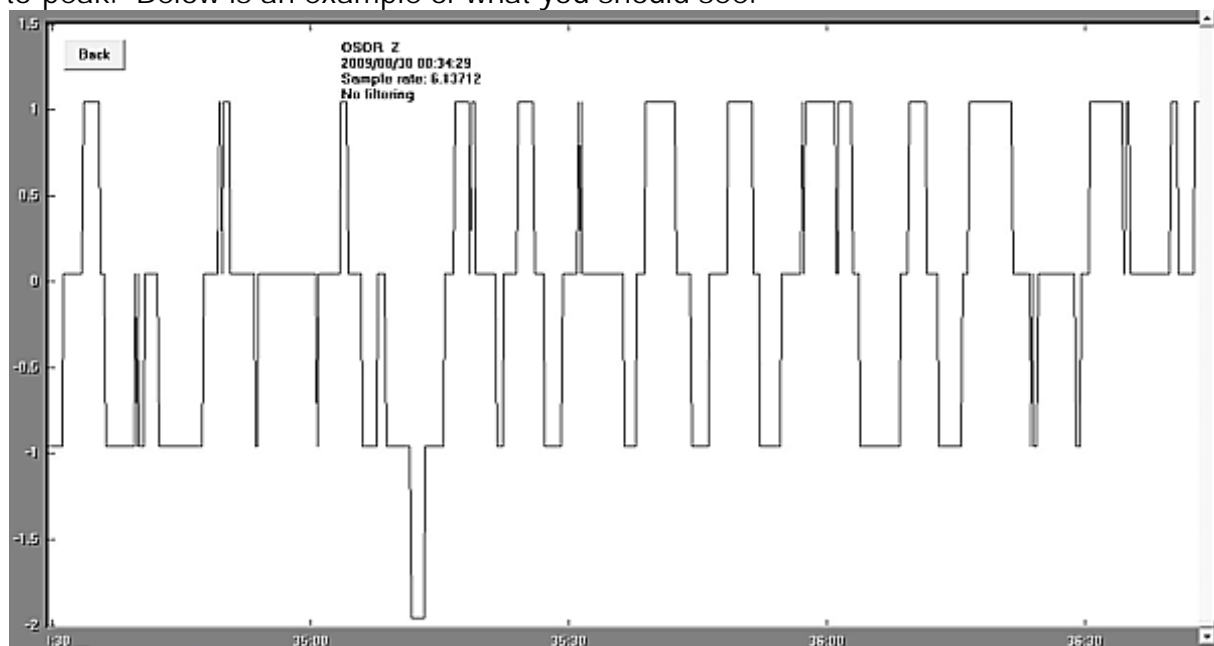
ELECTRONIC NOISE TEST

Electronic noise is present in all electronic circuits. Believe it or not, the electronic noise present in the AS-1 "Black Box" can help us diagnose potential problems.

To perform this test, unplug the seismometer from the black box. Then remove the acrylic cover and place a weight on top of the boom so that the magnet is resting firmly on the coil. This eliminates any signal created from the magnet/coil assembly. Below we used a stack of small wood pieces.



Next, plug the seismometer back into the "Black Box", connect to the computer. And start AmaSeis. The electronic noise when the boom is held fixed is just 3 counts peak-to-peak. Below is an example of what you should see.

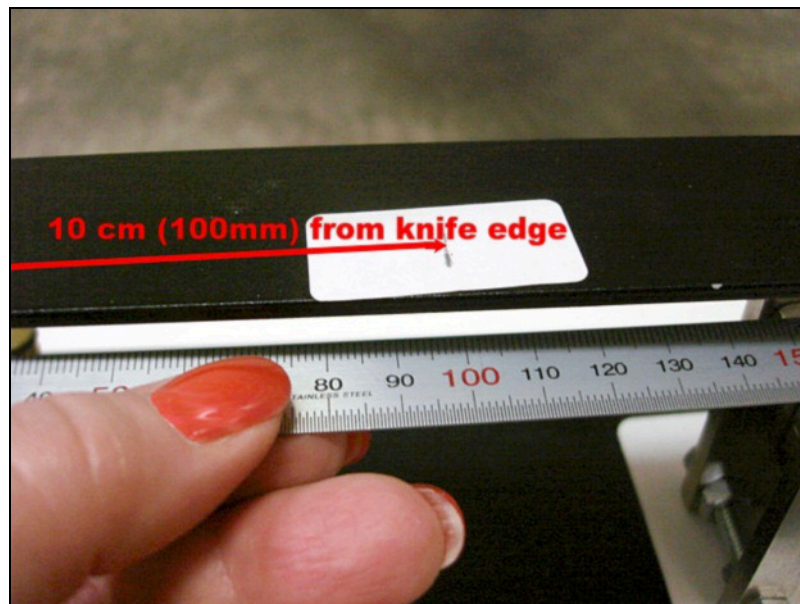


LIFT TEST

The lift test is a relative calibration of the AS-1 seismograph and is performed using a “step function” method. A small mass is placed on the boom of the instrument which is quickly removed.

First, unplug the seismometer from the “Black Box”.

In your Calibration Kit look for the bag containing a small label and a small piece of manila folder cut to 1 cm by 2 cm. Lay the 6” ruler on the boom edge and approximately 10 cm (100mm) from the vertical support place the white sticky label on the boom off to one side as shown below. Don't place it in the middle of the boom because you might brush the spring when you lift the weight. Next, with a pencil mark a line exactly 10cm from the vertical support.

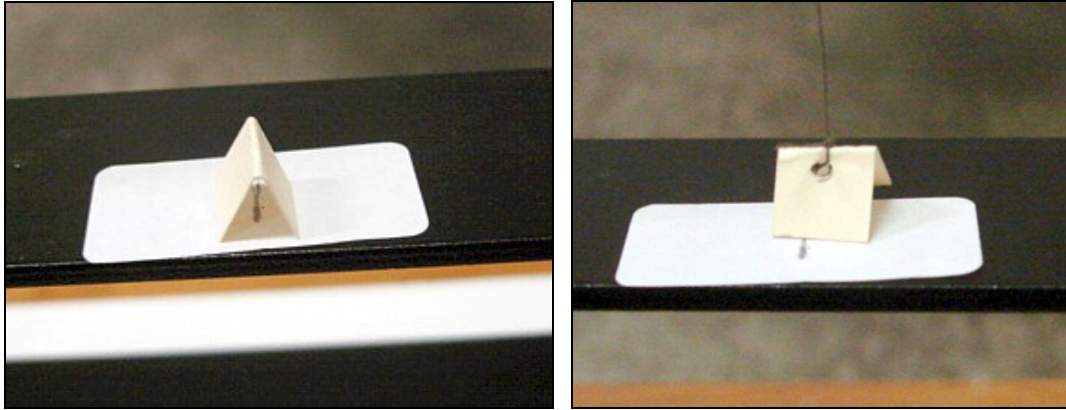


SAFETY NOTE:

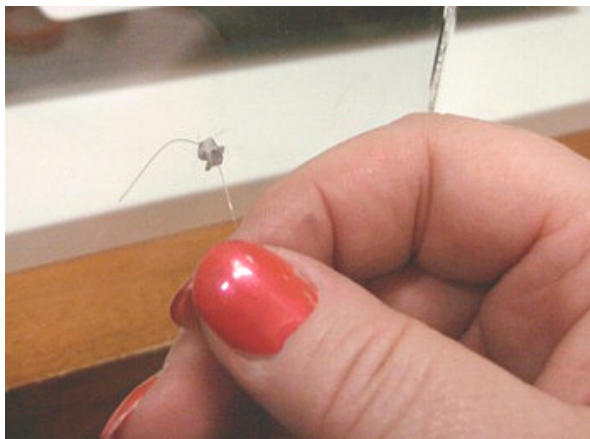
This test should NOT be done if you are using a glass cover. It is extremely difficult to safely drill a hole into glass.

Now, replace the acrylic cover onto the seismometer. Look straight down and place a mark on the acrylic cover exactly over the 10cm mark on the boom. Carefully drill a 1/8" hole through the plastic in this position. For those of you who have the “standard” acrylic cover it will be 14.5 cm from the end and 7.7 cm from the side.

Remove the small piece of manila folder from the bag and fold it in half. This is 0.034 grams in weight. Next, take a pencil and punch a small hole through the paper near the fold. Take the thread from the Calibration Kit, feed it through the hole and tie it in a knot.



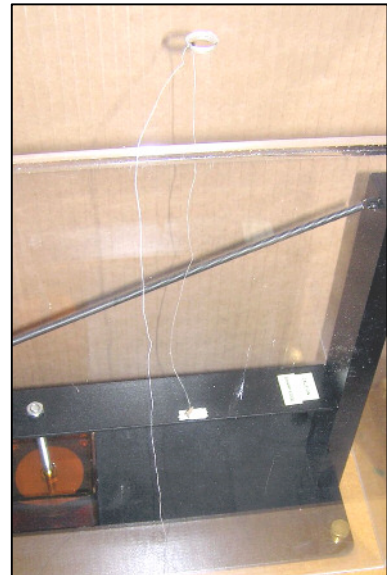
Measure about a yard of thread and cut it off of the spool. Reaching from the INSIDE of the acrylic cover, feed the thread through the 1/8" hole.



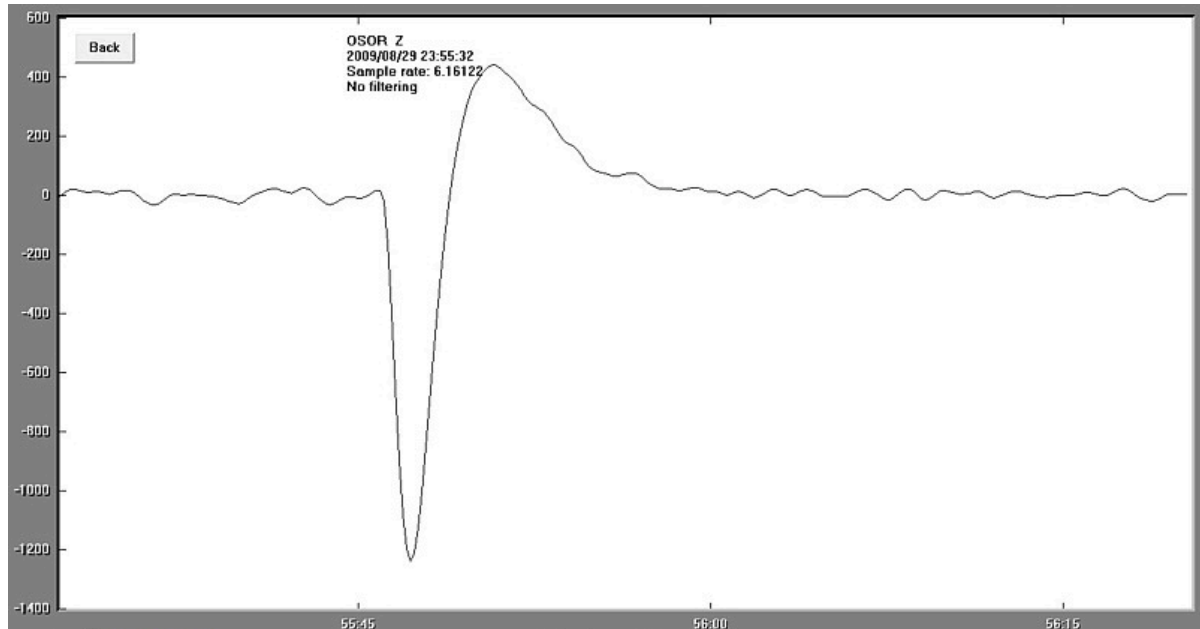
Replace the acrylic cover over the seismometer. Lower the paper weight down onto the boom where you placed the mark at 10 cm. Don't let the thread slip through the hole! Plug the seismometer back into the "Black Box" and start AmaSeis. Loosely hold the thread directly above

the paper weight but don't disturb the weight.

Let the noise level settle on the AmaSeis screen. Then, quickly lift the thread about an inch or two. You don't want to lift it all the way to the top because you might brush the spring creating unwanted noise.



Wait for a few seconds after lifting the weight. Then highlight the pulse on the AmaSeis screen and click the icon to plot an individual trace. Be sure to save your test in a SAC file.



Your pulse should have the following characteristics:

- amplitude of first trough (negative) = -1420 ± 150 counts
- amplitude of first peak (positive) = 480 ± 50 counts
- time from beginning of calibration pulse to first zero crossing = 3.0 ± 0.5 seconds

You can also check for correct polarity on your system. If the pulse first goes UP instead of down, swap the outside leads going into the "Black Box". Do NOT change the center ground lead into the "Black Box".

For more information see Larry Braile's "relative calibration" information on his web page at <http://web.ics.purdue.edu/~braile/edumod/as1mag/as1mag1.htm>.

INDUCTANCE TEST

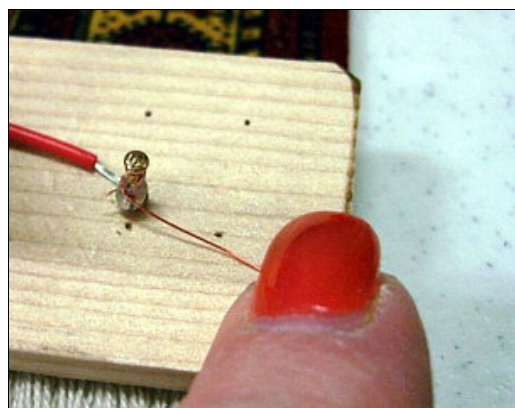
On rare occasions there may be a problem with the coil on the seismometer. A bump or drop might break one of the delicate wires causing an open circuit. Or it might chip the polyester coating on the wires causing it to short. This is a great test to determine the health of your coil. And it is a lot easier to do than you might think!

Initial steps:

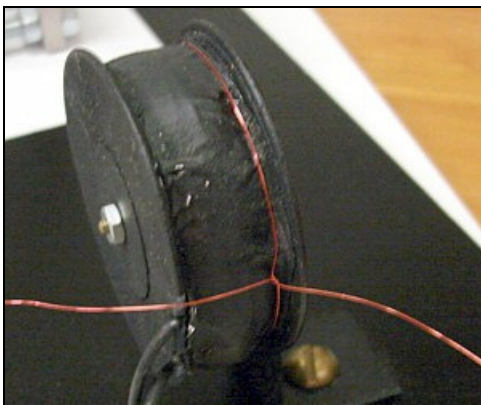
- Disconnect your seismometer from the "Black Box"
- Remove the cover from your seismometer
- Remove the boom and set it aside so that the magnet is away from the coil.



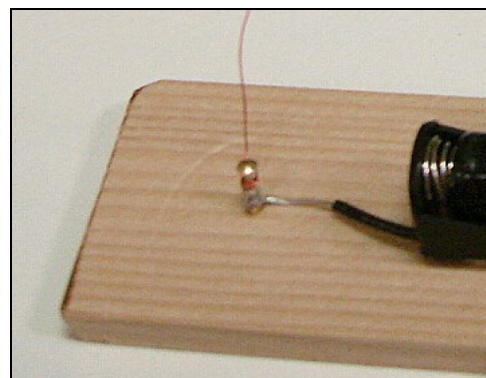
Next, find the 32 gauge magnet wire from the Calibration Kit. With a scissors, scrape off the polyester coating on one end of the wire. The color will change



Now find the board with the battery holder. Wrap the scraped end of the magnet wire tightly around one of the posts as shown. Make sure it is snug.



Feed the other end of the magnet wire underneath the coil and twist to secure. There should be ONE loop around the coil.

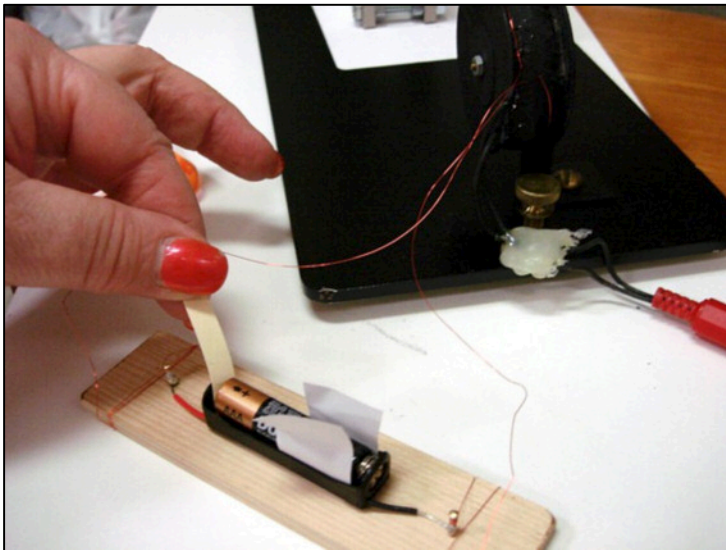


Scrape the coating off of the other end of the magnet wire and secure it to the other post.



Now cut two pieces of paper. One should be about $\frac{3}{4}$ " wide and the second should be about $\frac{1}{3}$ " wide. Slip the wide piece across the battery holder and lay the battery on it but don't press down. Next take the thinner piece and slip it between the positive contact on the battery and the battery holder. Now press firmly.

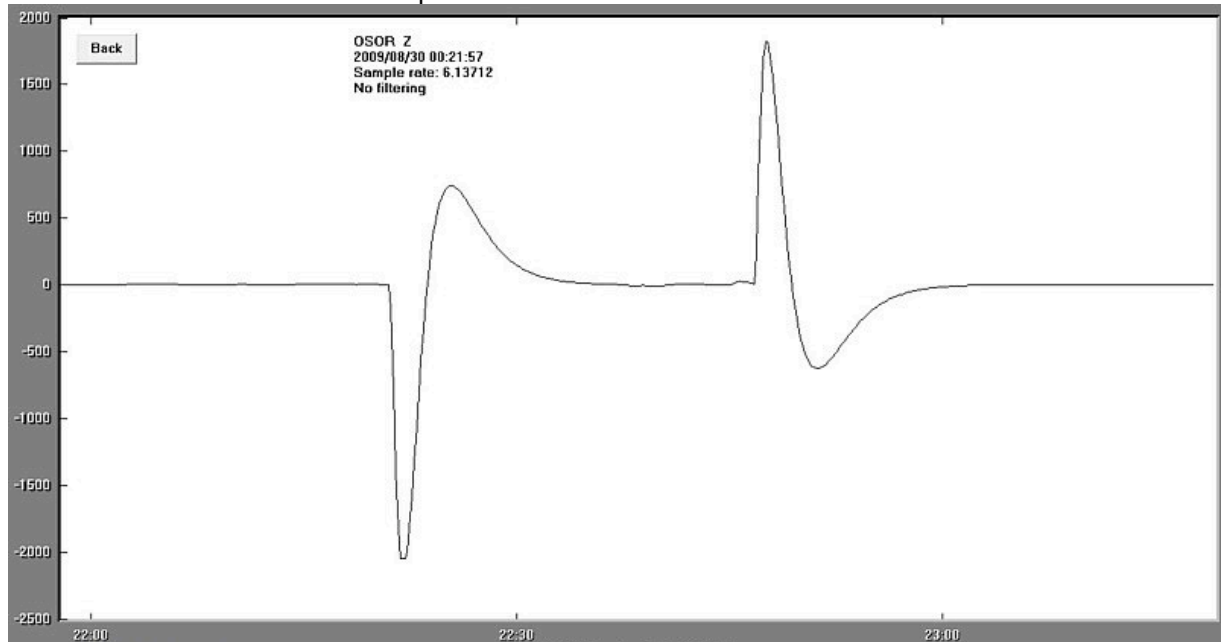
You are ready to connect the seismometer to the "Black Box". You don't need to replace the cover or the boom on the seismometer. Turn on the "Show Data Values".



Wait a few moments till the signal settles on the AmaSeis screen. The data values should be close to zero. Then while you hold the battery down with one hand, lift up on the narrow piece of paper with the other. This "turns on" the current. As you watch the AmaSeis screen you will see a pulse go down and then up again. Wait for a few seconds for the signal to settle around zero again. Then hold down the wooden support for the battery holder and lift the battery out with the wide strip of paper.

This "turns off" the current. You should see a pulse going UP on the AmaSeis screen. Wait a few seconds till the signal settles again.

Then with the cursor highlight both pulses and click the icon to plot a single trace. It should look like the screen capture below.



This calibration is independent of the AS1 spring and damping system.

Be sure to save this as a SAC file for future reference.

WHO TO CONTACT FOR MORE HELP

A special email address has been created just so that you can contact us for further help in calibrating your seismometer. In fact, if you have any questions at all, feel free to contact us at

sishelp@iris.edu

In addition, we highly encourage you to check out the IRIS Seismographs in Schools website at www.iris.edu/hq/sis. Here you will find a wealth of information on a variety of topics.

Under the "Community" tab check out the Discussion Forum. You can also post your questions here. If you have a question, you can be sure that other teachers have similar questions.

And, under the "Resources" tab check out the "FAQs" section (frequently asked questions). Not only can you find answers to many of your questions, you will find video clips on the entire process of setting up your seismometer!