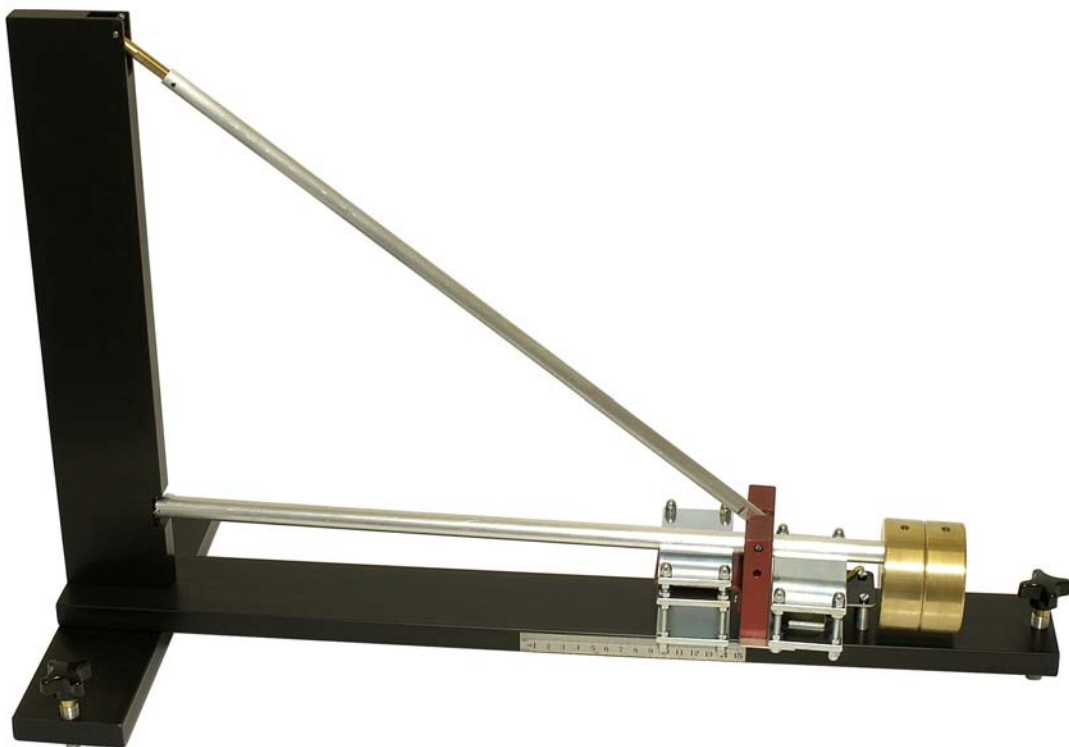# INSTRUCTION MANUAL
SEP SEISMOMETER SYSTEM

SEP SEISMOMETER SYSTEM

The SEP Seismometer System was developed by a partnership of the Gatsby Science Enhancement Programme (SEP), the British Geological Survey (BGS) and Middlesex University Teaching Resources (MUTR). In addition to the seismometer itself, the partnership also produced a booklet 'Seismology' as part of SEP's 'Innovations in practical work' series. This booklet provides a background to seismology aimed at secondary science teachers; a number of items of low-cost equipment were also developed with to support simple classroom activities, and the booklet contains student activity sheets and teachers' notes. The CD-ROM that accompanies this instruction manual includes more detailed background about seismology, as well as the software that is required for the SEP Seismometer System.

ACKNOWLEDGEMENTS

FURTHER INFORMATION

Other seismology practical kits and copies of the SEP publication *Seismology* and can be purchased from Middlesex University Teaching Resources (www.mutr.co.uk).

Visit the SEP website (www.sep.org.uk) for information on how to become an SEP Associate and how to obtain further curriculum resources.

Gatsby Science Enhancement Programme
Institute of Education, University of London
Room 202, 11 Woburn Square
London WC1H 0AL
Email: sep@ioe.ac.uk
Web: www.sep.org.uk

CONTENTS

ABOUT THE SEP SEISMOMETER SYSTEM

The SEP Seismometer System uses the same basic principle underlying all seismometers, which is that of inertia – seismic waves from an earthquake make the ground move relative to the recording device. In the case of the SEP seismometer, there is a large mass on the end of a boom: this stays where it is as the ground moves beneath the seismometer, and this relative movement is recorded.

The SEP seismometer is based on what is often called a 'garden gate' design, since the boom is able to swing from side to side. Attached to the boom is a set of 'sensing magnets' and a 'sensing coil' is mounted on the base of the seismometer; when the boom moves, the magnets move relative to the coil, and an electrical signal is generated in the coil.
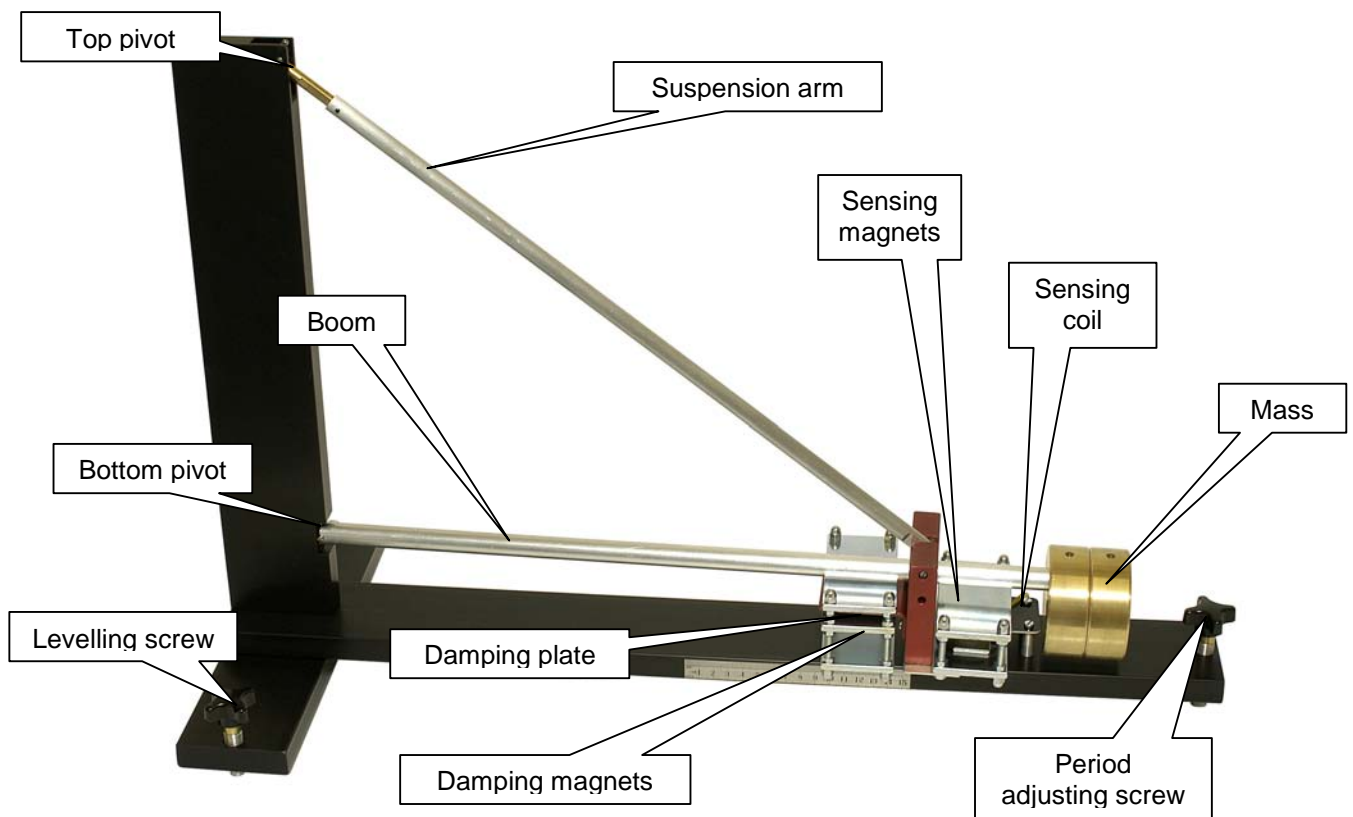
When it is set up, the tilt of the seismometer is adjusted with the boom sloping slightly downwards away from the bottom pivot, so that the boom oscillates with a period of about 20 seconds. The oscillation is damped, through the use of a damping plate on the boom, which is placed in the magnetic field between the damping magnets.

Also included in the SEP Seismometer System are an electronics box and the AmaSeis software. The sensing coil is connected to the electronics box, which amplifies and digitises the signal. The electronics box is connected to a computer running AmaSeis software, which enables the signals from the seismometer to be recorded and analysed.

COMPONENTS

The SEP seismometer consists of the following components

1)   Long frame base (with single levelling screw and scale marks)
2)   Short frame base (with twin levelling screws)
3)   Frame upright (with top suspension point suspension rod and vertical roller bearing)
4)   Boom arm (with aluminium damping plate and boom bracket)
5)   Sensing coil (with phono plug connector)
6)   Sensing magnets (assembled in steel cage)
7)   Damping magnets (assembled in steel cage)
8)   Brass masses (with locknut)
9)   Electronics box, mains adaptor and serial RS232 lead.

Boom arm

Tungsten carbide roller bearing on one end, bracket holding aluminium damping plate and sensor magnets (or sensor coil) on the other end, with a hinged suspension rod.
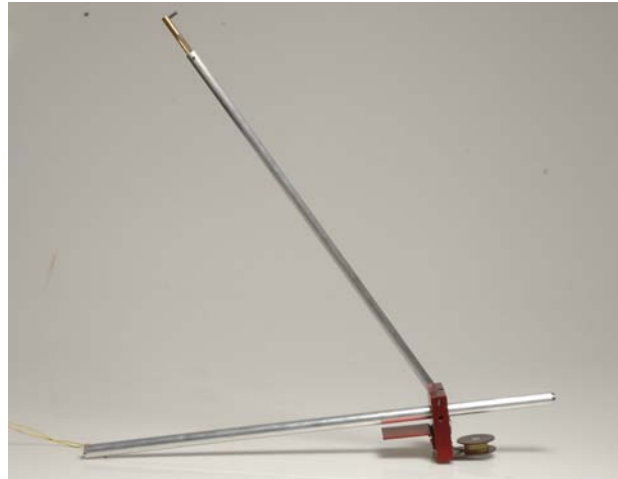
The frame of the seismometer can be assembled anywhere, however it is best to attach the suspension rod and boom only when the seismometer frame is at its operational location. The seismometer frame is constructed of aluminium so take care not to overtighten the set screws holding the frame together.

Top row: damping magnets in cage (left), sensing magnets in cage (right).

Bottom row: brass masses.

SITING THE SEISMOMETER

Since the seismometer acts as a sensitive pendulum, it is affected by small amounts of tilt of the surface it rests on. Thus, the seismometer only works satisfactorily if it placed in direct contact with a solid floor. A table, a suspended wooden floor or the upper floor of a building are not suitable. If possible orientate the seismometer either North-South or East-West. The seismometer needs to be protected from air currents and drafts - a simple box cover made of cardboard, wood or insulation will work well. However, if you wish to have the seismometer on display, then a cover made of transparent sheets (Perspex or toughened glass) will be required. The seismometer electronics run from mains power and the system also needs to be connected to a PC for recording the data. (If the PC is connected to the school network then data can be remotely viewed across the school network)

ASSEMBLING THE SEISMOMETER

Step 1: Assembling the frame

First attach the long frame base to the frame upright with two set screws.

Next attach the short frame base to the frame with two set screws.

Step 2: Attaching the boom arm

The seismometer can be set up in two ways:
- moving magnet mode (with the sensor magnet on the boom and the sensor coil on the baseplate)
- moving coil mode (with the sensor coil on the boom and the magnet on the baseplate).

As shipped, the sensor magnet is attached to the boom (*moving magnet mode*). The advantage of this arrangement is that, with the coil attached to the baseplate there are less problems attaching the cable to the electronics box. This section describes how to set the seismometer up in this mode.

Schematic diagram showing seismometer assembled in moving magnet mode.
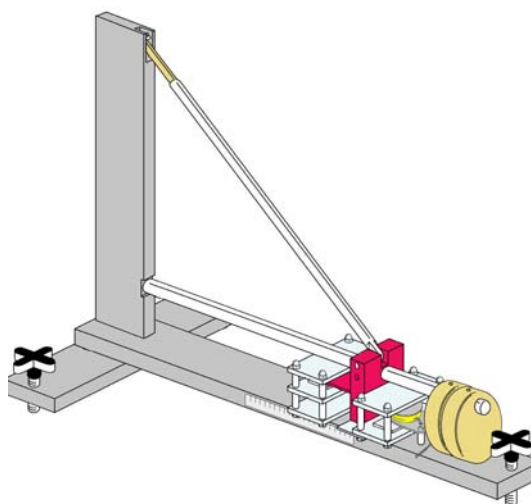
When you unpack the seismometer, you should find that the sensor magnet arrangement is already attached to the boom arm.

You will need to attach the sensor coil to the seismometer frame - *but this must be done AFTER the boom arm is in place*. The brass masses are attached last of all.

The following photographs show the sequence of actions.
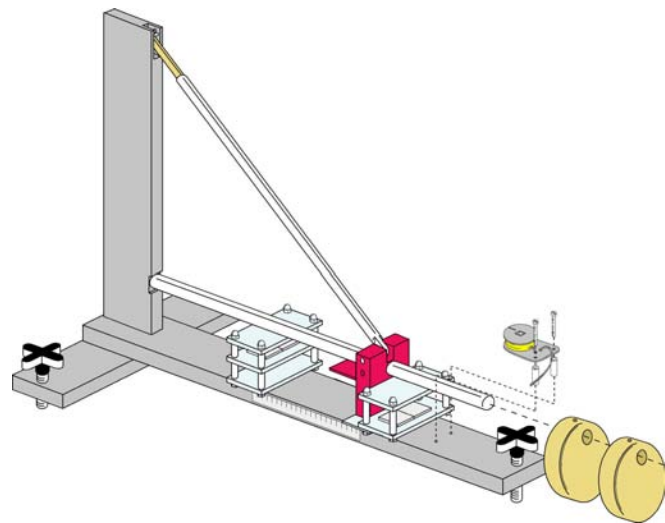
Place the seismometer on the floor where you plan on operating it. Put the steel cage with the damping magnets on the baseplate near the upright. Gently hook the top pivot point into place, and then rest the boom arm on the bottom pivot point. The length of the boom arm is factory set and should not need adjusting.

Top pivot point   *Bottom pivot point*
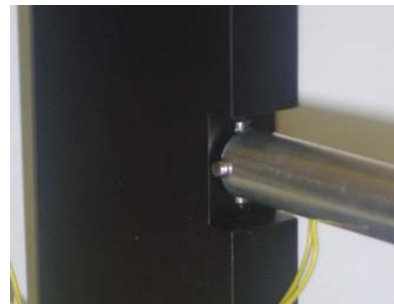
Ensure that both pivots are located centrally and that only the roller bearings are in contact (the brass rod must not touch the frame at the top pivot point and the boom arm must not touch the frame at the bottom pivot point)

Slide the steel cage with the damping magnets over the damping plate connected to the boom.

Now you can attach the sensing coil to the baseplate with the bolts and spacers provided.
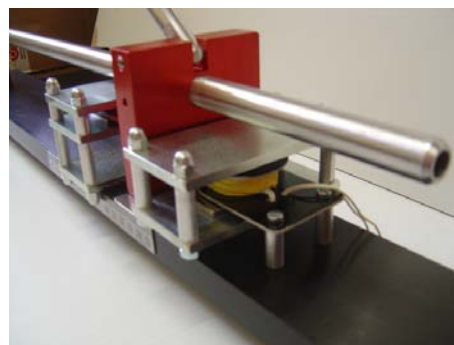
Assembled view of moving magnet setup

Add the masses by sliding onto the end of the boom arm and securing the locknuts. The side view of the arrangement should now look like the photograph below.

Alternative Step 2: Attaching the boom arm (moving coil mode)

The previous section explained how to set up the seismometer in *moving magnet mode.* Although this is simpler, the disadvantage of this arrangement is that because the sensor magnet is attached to the boom arm, there is potentially a small effect on the data caused by fluctuating magnetic fields near the seismometer causing the boom arm to move (e.g. from mains power surges in nearby cables or mov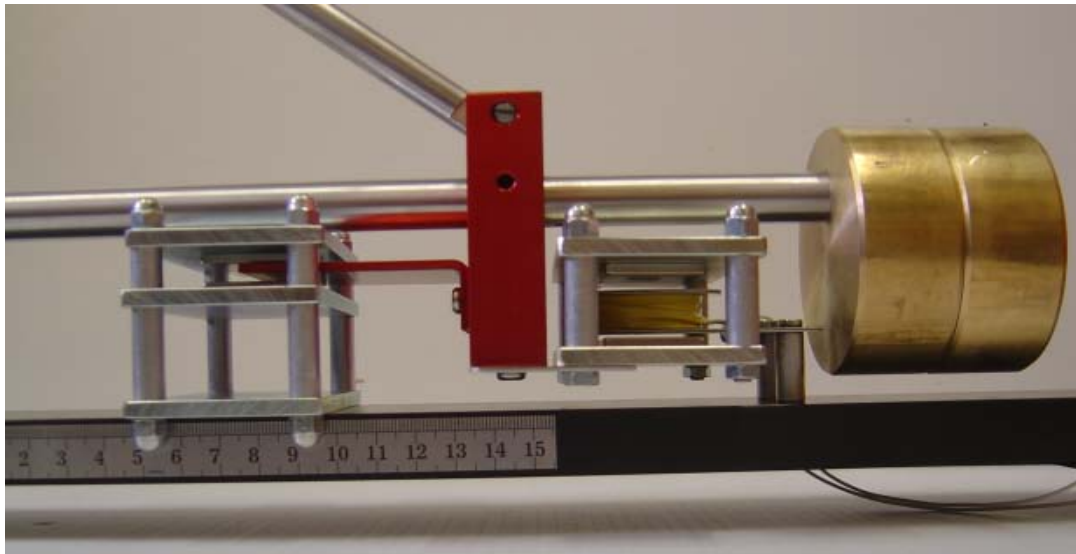ements of large ferrous objects nearby). If you think that your data is being affected, you can set up the seismometer in *moving coil mode* with the sensor coil on the boom arm and the sensing magnets on the baseplate.

Detail of boom arm in moving coil mode
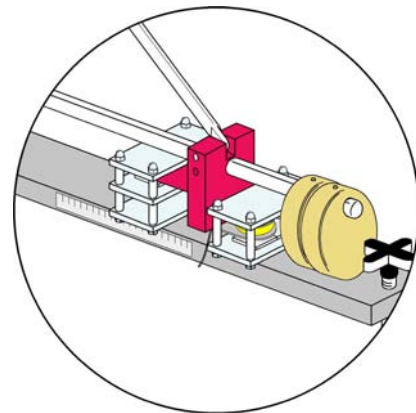
For moving coil configuration you should attach the coil to the boom arm in place of the magnet assembly.
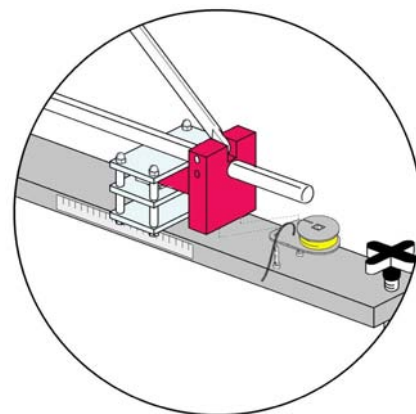
Place the boom arm roughly in place with the sensing coil inserted into the sensing magnet cage and the damping plate in the damping plate magnet cage. If desired, the sensing magnet cage can be secured to the baseplate with two small bolts.
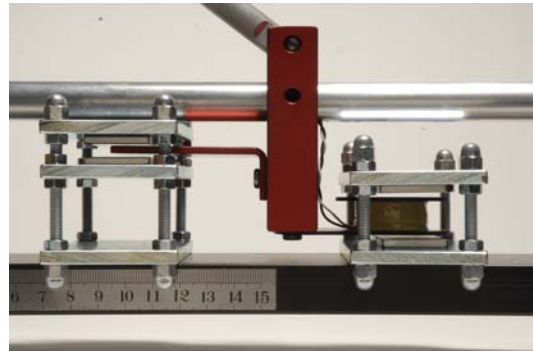
Attach the brass masses on the end of the boom arm.
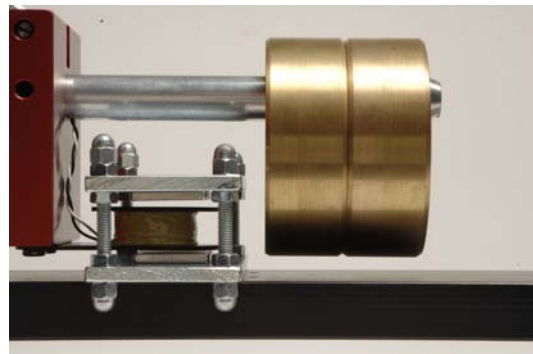
Gently check again that both roller bearings are centred.

Top pivot point   *Bottom pivot point*
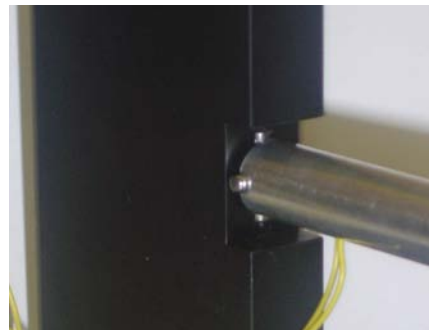
Step 3: Levelling the seismometer

The seismometer is levelled by adjusting one of the screws on the short base frame.

The screw on the long base frame (by the mass) is used to adjust the period of the seismometer by changing offset between the top and bottom hinges.

Adjust the levelling screws on the short frame base until boom is swinging freely. Make fine adjustments of the levelling feet on the short frame base until the boom arm and brass mass are stable along the centreline of the long frame base.
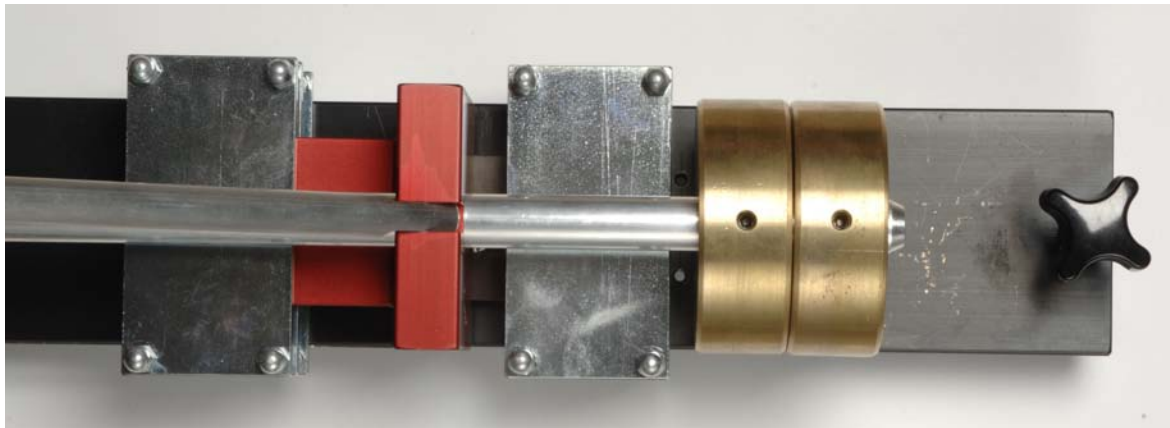
Step 4: Adjusting the natural period

The natural period of the seismometer depends on the angle of the line joining the top suspension point and the roller bearing point to the vertical. The closer this angle is to vertical the longer will be the natural period of the seismometer. The period can be adjusted by altering the levelling screw on the long frame base (next to the mass).

At this stage you want the seismometer to be oscillating freely so it is important to ensure that the damping magnets are kept away from the damping plate (keep the leading edge of damping magnet cage below 3 cm on the scale).

- *Either:* Connect the phono plug from the sensor coil to an oscilloscope or datalogger with +- 50mV input range and monitor the signal on a computer oscilloscope display.
- *Or:* measure the natural period of the system with a stopwatch.

Disturb the seismometer mass very gently by blowing on the mass from a distance of about 20 cm.

Adjust the levelling screw on the long frame base until the natural period of the seismometer reaches 15-20 seconds.

The following screen dumps were taken during a setup procedure and show the recorded signal from the coil after the mass is disturbed by gently blowing on it (using Fourier Systems Multilink datalogger with +-50mV input).
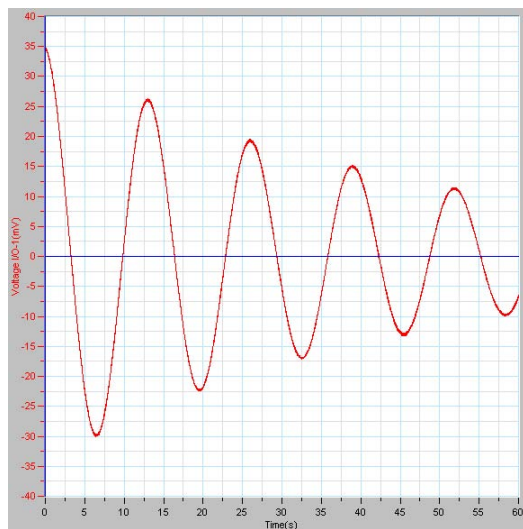
13 second natural period
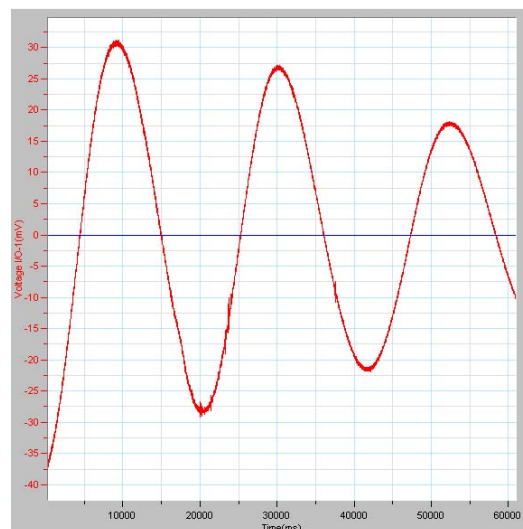
21 second natural period

With the damping magnets well out of the way the mass should oscillate for a few minutes after being disturbed, friction from air resistance and electrical energy generated in the coil will cause the oscillations to decay eventually.

Step 5: Adjusting the damping

Now slide the damping magnet cage along the base until a situation of critical damping is achieved, this will be when the damping plate is approximately halfway into the damping magnet cage. Critical damping is achieved when the mass returns to its equilibrium position without overshoot. This can be determined roughly by eye if the mass is perturbed visibly, or more accurately using a datalogger.
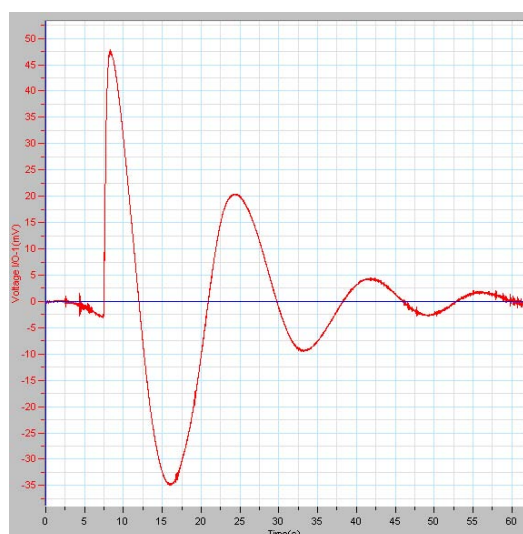
Underdamped response to an impulse
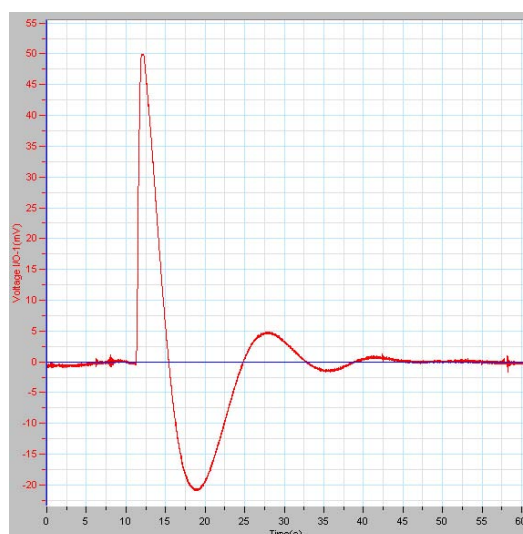
Slightly underdamped impulse response

Try to run your seismometer either critically damped or slightly underdamped. A seismometer that does not have enough damping applied will produce data that oscillates too many times after a signal is detected. A seismometer that is overdamped will be less sensitive to small signals.
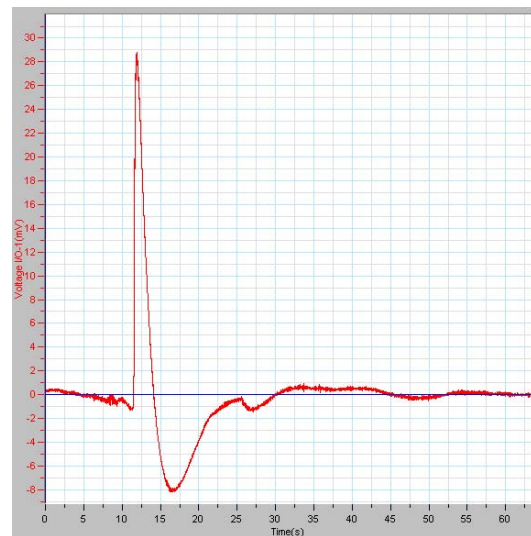
Critically damped impulse response

Cover your seismometer with a box to prevent drafts and reset the sample rate on your datalogger to about 20 sps. With a reasonably quiet site you should see a random looking signal due to the background seismic noise of the earth (called microseismic noise), which is generated by ocean waves. When there is a big storm approaching from the Atlantic you should notice this signal increases in amplitude (you can use your seismometer to predict the weather!). See appendix 2 for more information on background noise.
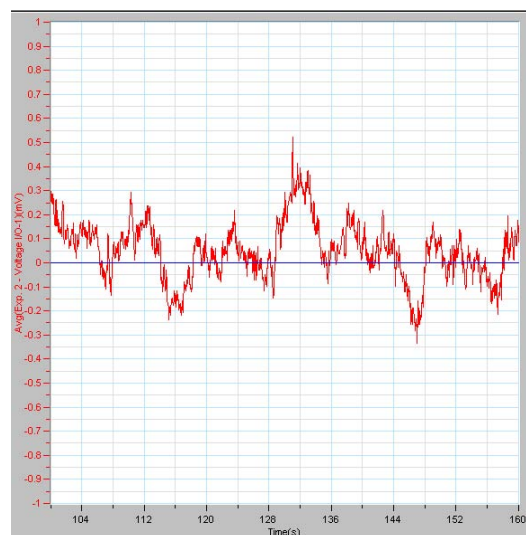
Background noise

CONNECTING THE SEISMOMETER TO A COMPUTER

The electronics box with the SEP Seismometer contains an amplifier and filter circuit and a digitiser circuit that converts the changing voltage into digital data readable by the AmaSeis program (see next section).

It is best to wait until you have set up the seismometer for the correct period and damping before connecting it to the SEP amplifier/digitiser. The large signals created during the setup process will swamp the sensitive datalogging software otherwise.

RS232 to PC   Power

For most sites and with a standard SEP coil and magnet arrangement a gain value of x100 will be sufficient (both dip switches set to on):

1	2	Gain
On	On	100
Off	On	200
Off	Off	500

Input from seismometer

Gain selection   Power LED
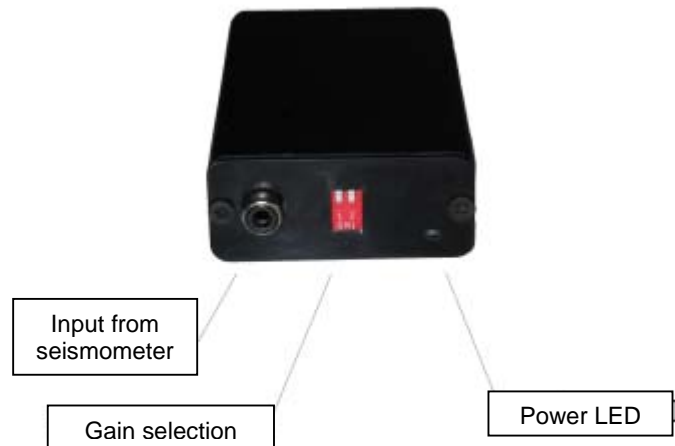
Connect the lead from the sensing coil to the terminal block on the input lead to the electronics box, and connect the electronics box to a 12v d.c. power supply (a mains adapter is supplied).

Use the serial RS232 male-to-female lead to connect the electronics box to a spare serial port (called COM ports by Windows operating system) on the computer. (If your computer does not have a serial port you can use a cheap USB to serial converter cable, which will create spare COM ports.)

Specifications

Power supply 12 V d.c.
Band pass filter from 0.016 Hz to 5 Hz
Adjustable gain x100, x200 or x500
Digitiser 16 bits at 20 samples/sec

USING AMASEIS SOFTWARE WITH THE SEP SEISMOMETER SYSTEM

AmaSeis is the software that records and displays the data generated by the SEP seismometer system. It is available only for Windows PC's and runs under Windows XP, 2000 and 98ME (currently not tested under Vista and does not work with Win95).

Installing the AmaSeis software

The AmaSeis program (written by Alan Jones) is a freely available software package that can be used to monitor and record seismic data but can also be used as a stand-alone program to view and analyse seismic data downloaded from the internet. The installation package AmaSeisSetup.exe is included on the CD-ROM with the SEP Seismometer System, or you can download the latest version from:
http://www.geol.binghamton.edu/faculty/jones/AmaSeis.html

Save the setup program to your hard disk, and then run the program by double-clicking (you might need to get your system administrator to install the software for you). If you get a security warning when you try to install the software, click **Run** and then **Yes** to continue.
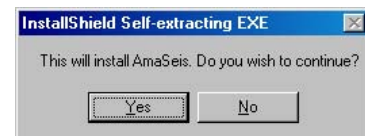
A standard setup sequence will then start, prompting you for your name and institution, default values will be OK at this stage. If possible try to install the software in the default destination (c:\AmaSeis) and assign it to the default Seismology Program Folder.
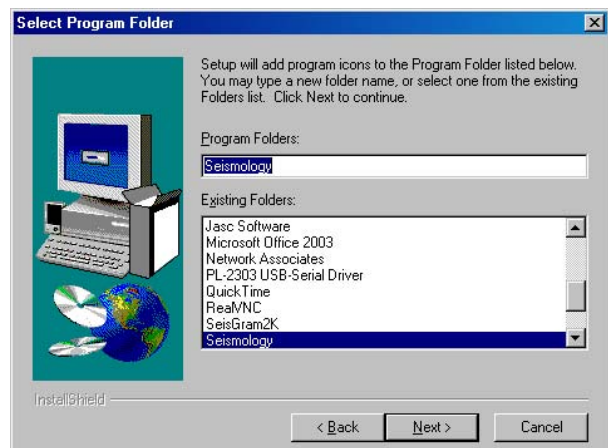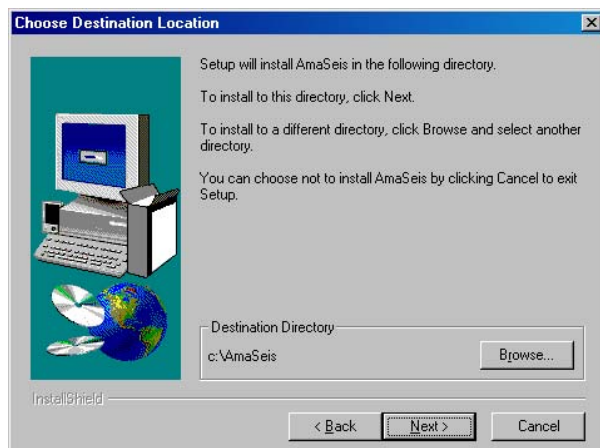
The installation program creates a desktop icon for AmaSeis. Double-click to start the program.

AmaSeis will store all settings in a file called *AS1.ini* so that you should only need to make changes once when you first start the program.

Device settings

Start AmaSeis and check that the Device Settings is set to SEPUK-1 (the SEP Seismometer System)
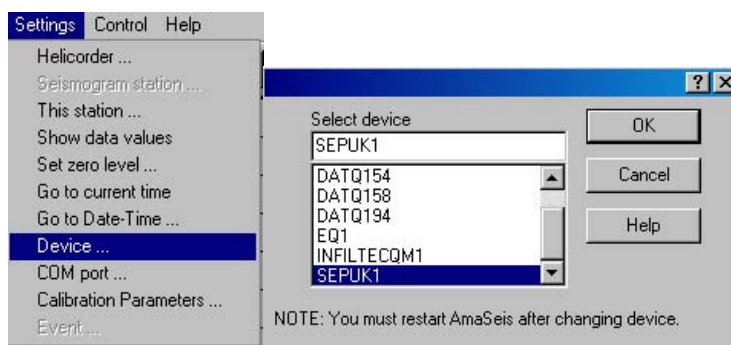
Ensure that the COM port setting corresponds to the COM port being used (for a desktop with direct serial port attachments this will probably be COM1 or COM2). If your computer does not have serial ports then you will have to use a USB-Serial adaptor, this will come with software which will assign a virtual COM port number to your connection which will probably be a much higher number
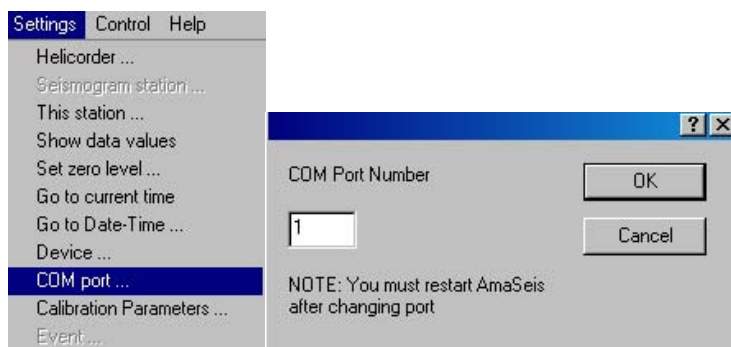
Note that after changing device and COM port settings you will need to stop and restart AmaSeis for these to take effect.

Station settings

When you first start using AmaSeis at your school it is necessary to assign your station a name and station code. Make sure that you register your station with the BGS school seismology network at: www.bgs.ac.uk/schoolseismology
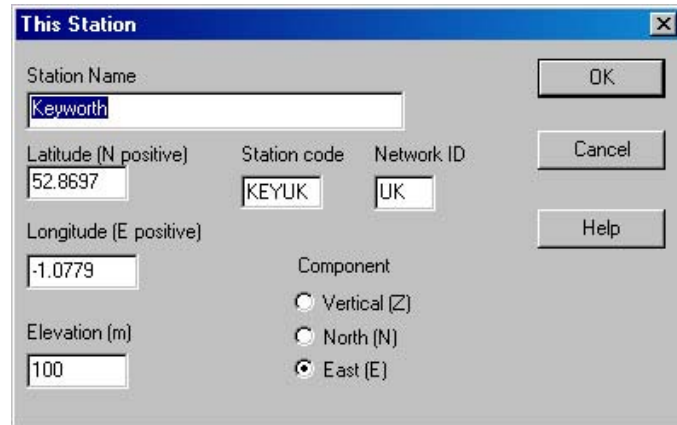
With AmaSeis running, click on: Settings > This station.

A dialogue box will appear. Fill in the details for your school - choose a 4 or 5 letter code for your school station. The correct network code for schools in the UK is UK. All of these values will then be stored as header information in any data files that you record, enabling other users to discover where the data was recorded.

Your school Latitude and Longitude can be found by using a GPS unit, an Ordnance Survey map or by entering your school postcode into an online mapping site like www.multimap.co.uk.

The component for your sensor refers to the direction of ground motion to which your sensor is sensitive. This corresponds to the direction at right angles to the seismometer boom arm. If possible your seismometer should be orientated so that this direction is either pointing North or East. By convention seismologists orientate their seismometers so that ground motion towards the North or East direction gives a positive signal.

This information only needs to be filled in once only; the data is stored in a text file called AS1.ini, which is read each time AmaSeis is run. Once these station parameters are completed it is necessary to stop the AmaSeis program and then start it again. The new station code should appear at the top of the display screen, for example:

Setting up the display

AmaSeis records data continuously to disk while it is running. It uses a simple directory structure within the c:/amaseis home directory with folders for years, months and days. Within each day folder each hour's data is recorded as a separate file.
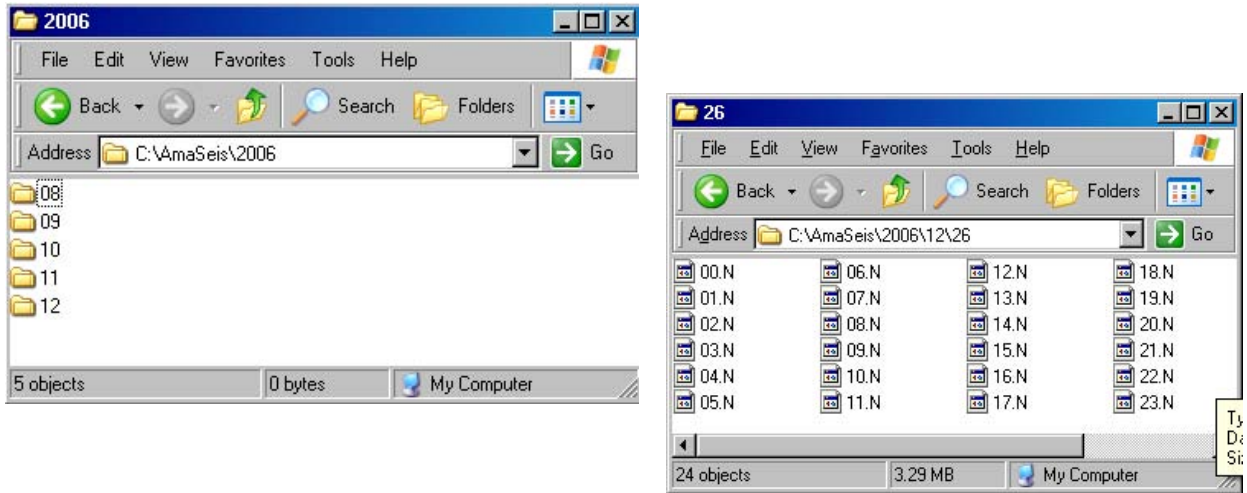
The continuous data files that AmaSeis generates are formatted as simple lists of binary numbers; it is only event files of selected data that can be saved as SAC format data.

Each day's data takes up 3.3 Mbytes (that's 1.2 Gbytes per year) so you should not run into too much trouble with disk space unless you have a very old computer. To delete unwanted data you just delete the raw data files using Windows Explorer.

You should ensure that AmaSeis can scroll back to previous days' data by setting the Settings > Helicorder options to 'One hour' (Horizontal time limit) and '999' (Days to retain records).
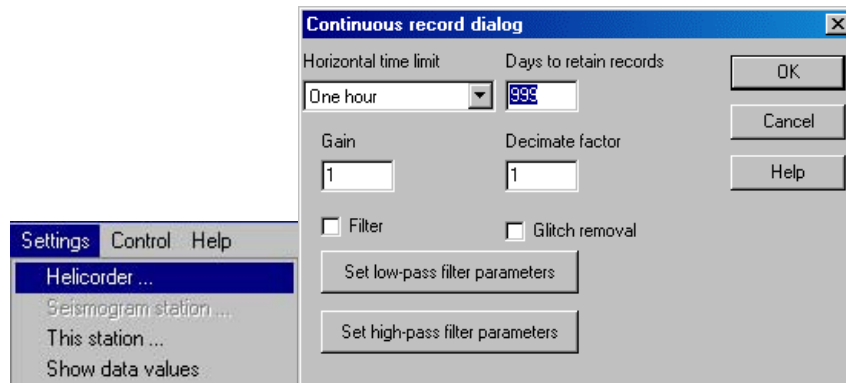
Zero offset

It is possible that when you start up AmaSeis, the trace being recorded will have a slight offset from an average value of zero. On the helicorder display this will show up as your data line (wiggly black line) being offset from the marked zero line (blue):
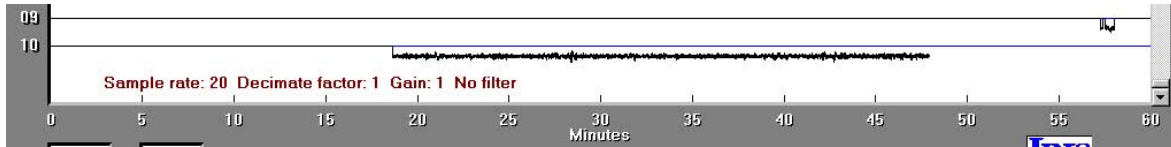
Data showing a slight offset or DC bias

This can be corrected by applying a zero offset value (in counts) to the data. An indication of the appropriate value to use can be found by monitoring the actual data values being recorded.
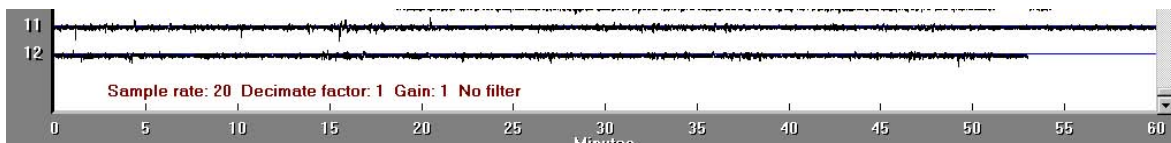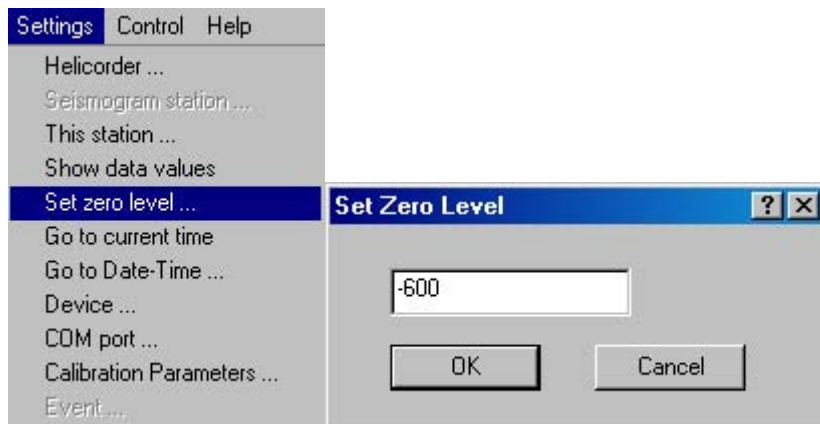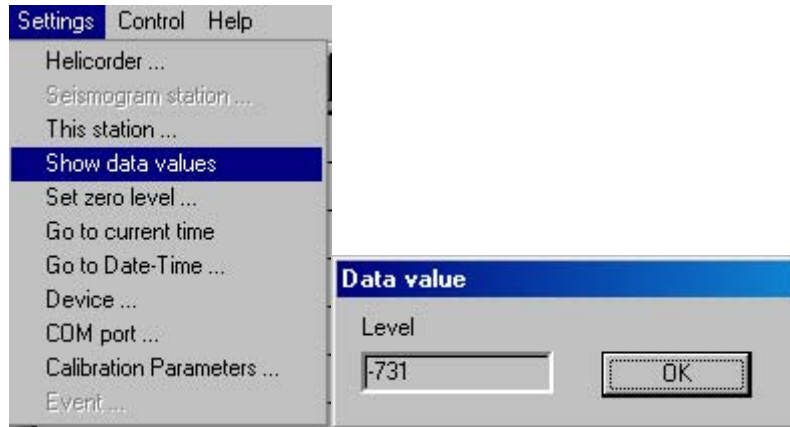
Data with DC bias corrected

FILTERING DATA

AmaSeis records all continuous data to disk without any software filters applied. However, it has the option of displaying data on screen with a variety of filters applied.

Applying a filter

To emphasise the data from large distant earthquakes and to minimise the data from nearby noise sources, a good filter to apply to the helicorder plots is a 10 second low-pass filter.
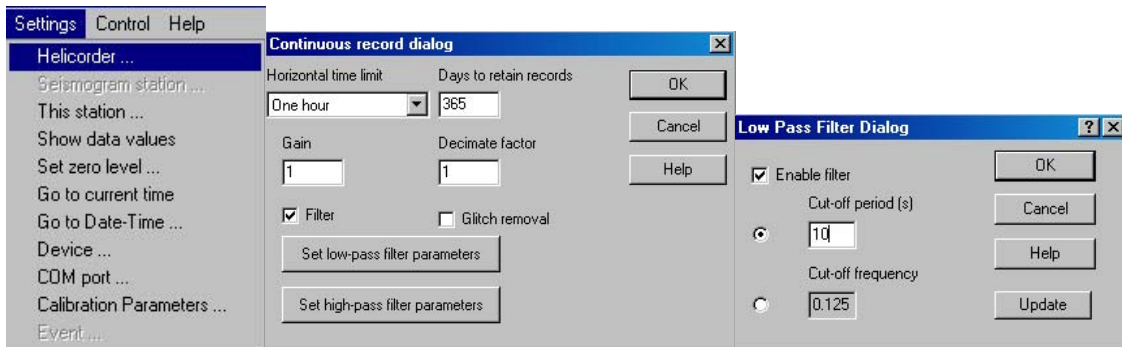
Unfiltered record of M6.7 event in Papua New Guinea
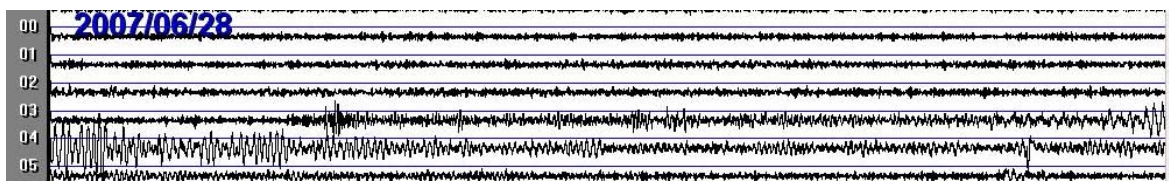
Filtering with a low pass filter (10 seconds) shows the seismic waves arriving more clearly.
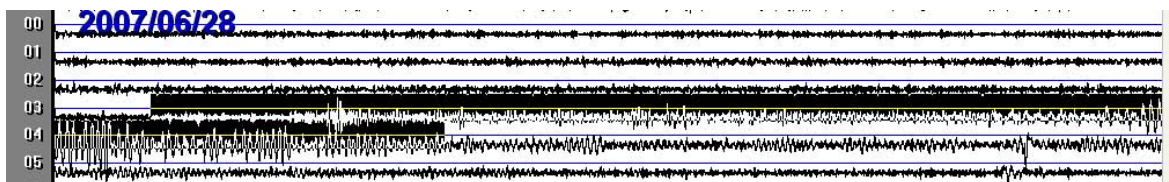
To analyse data further, you can select the data that you are interested in, by dragging with the mouse, and then clicking on the Extract Earthquake button:

Once the selected data is transferred to the analysis window, all filtering that had been applied in the helicorder display is removed, and you start by seeing the raw data.
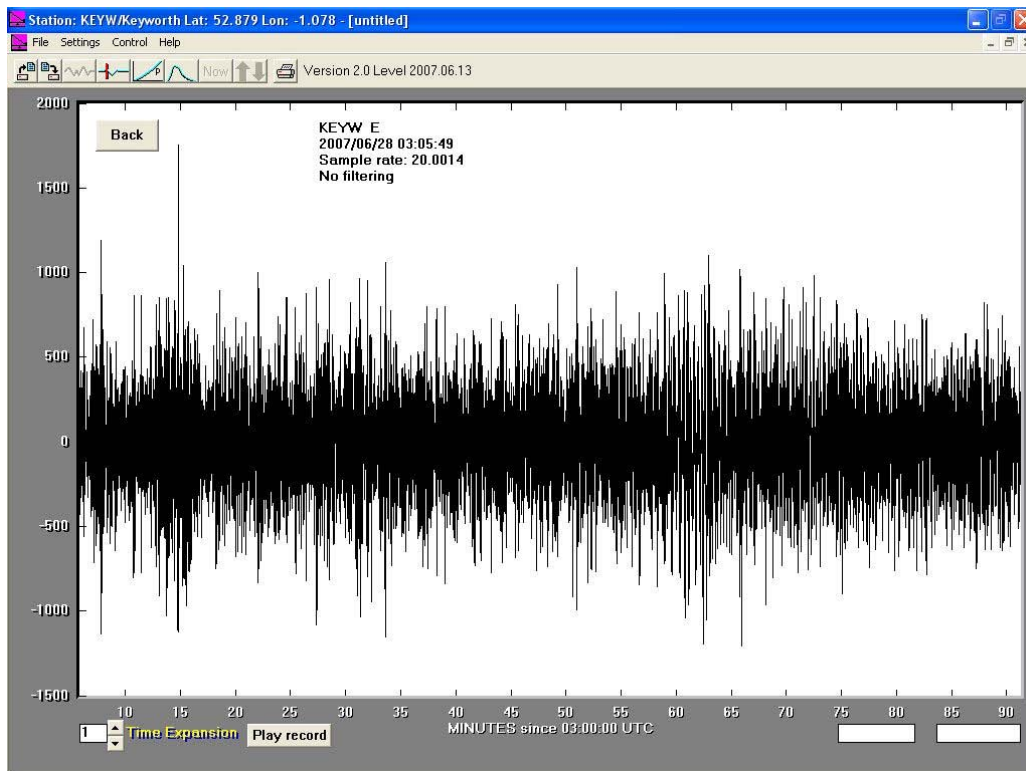
Analysis window

If this data contains the record of an earthquake that you wish to save you can do this now by selecting File > Save as.
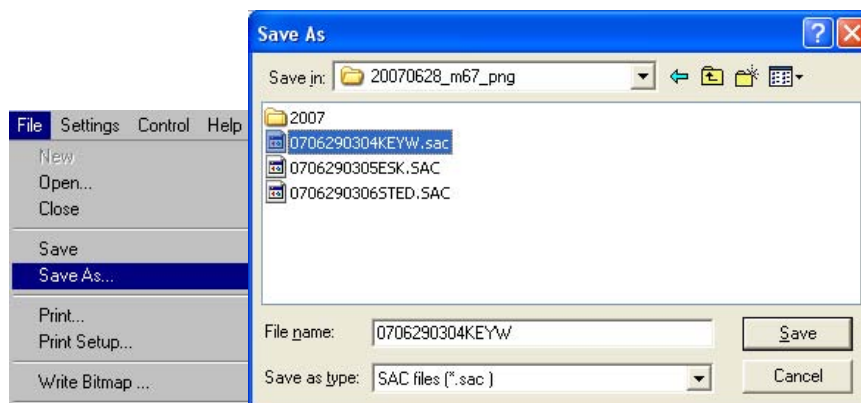
The filenaming convention to use is to name the file: yymmddhhmmSTNM.sac

where: yymmdd is the date of the event (year month day)
              hhmm is the start time of the file (hour minute)
              STNM is your stations 4 or 5 letter station code (eg KEYW)
              .sac is the automatic file extension that indicates the data format.

Further Analysis

New filters can be applied to the data in the analysis window using the Control menu:
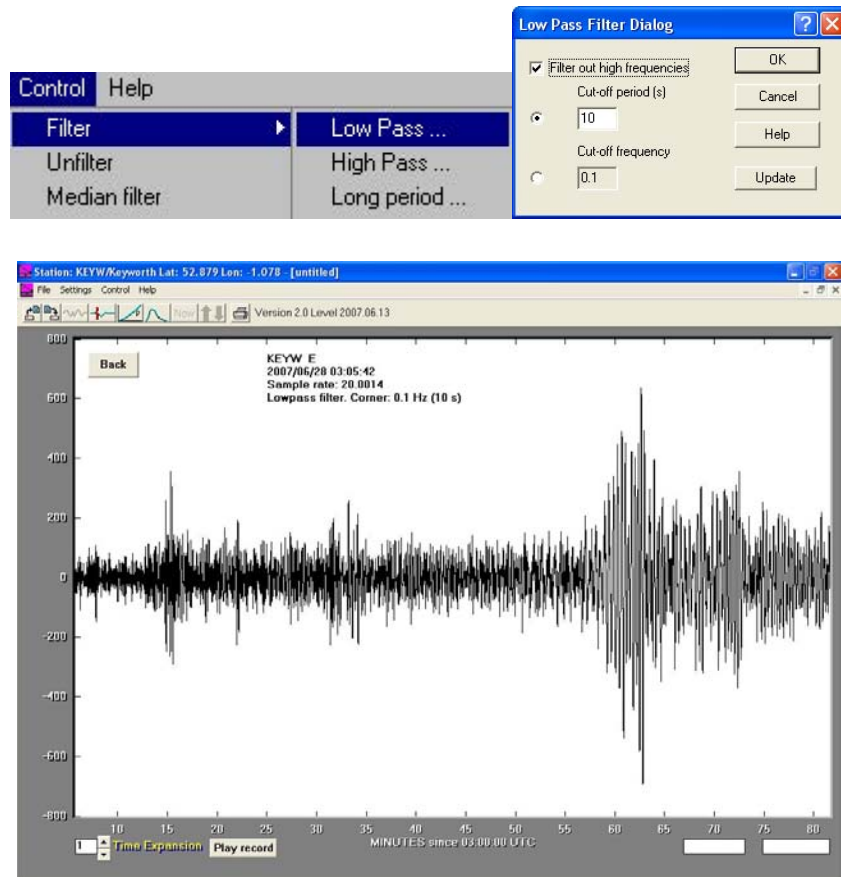
You can apply the same filter twice to enhance the data further:
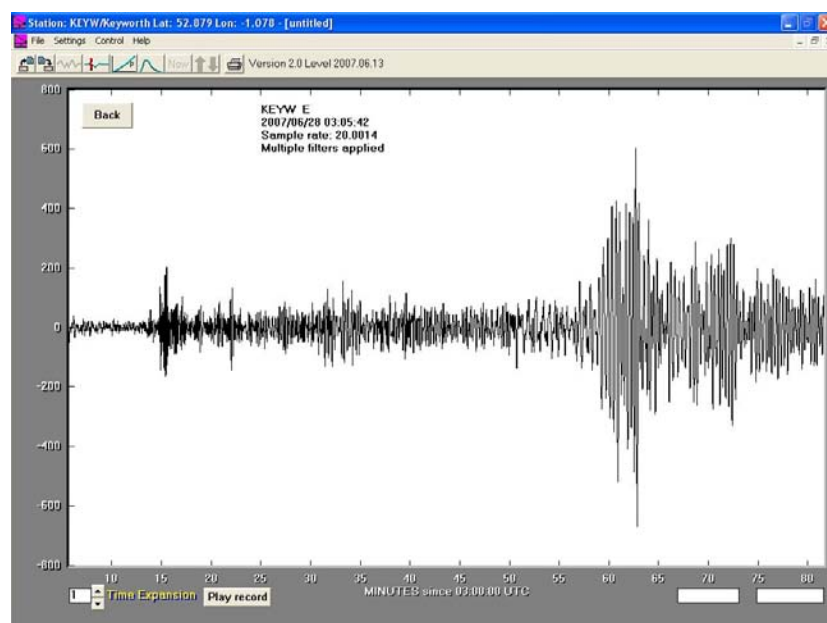
Travel time graphs

Once you think you can identify some key phases on your seismogram you can view the seismogram on a travel time graph by clicking on the 'P' Travel Time Curves button:
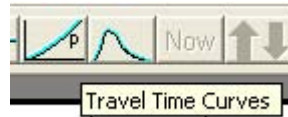
You will be asked to enter the depth of the earthquake. If you do not have any data about this, then use the default value.
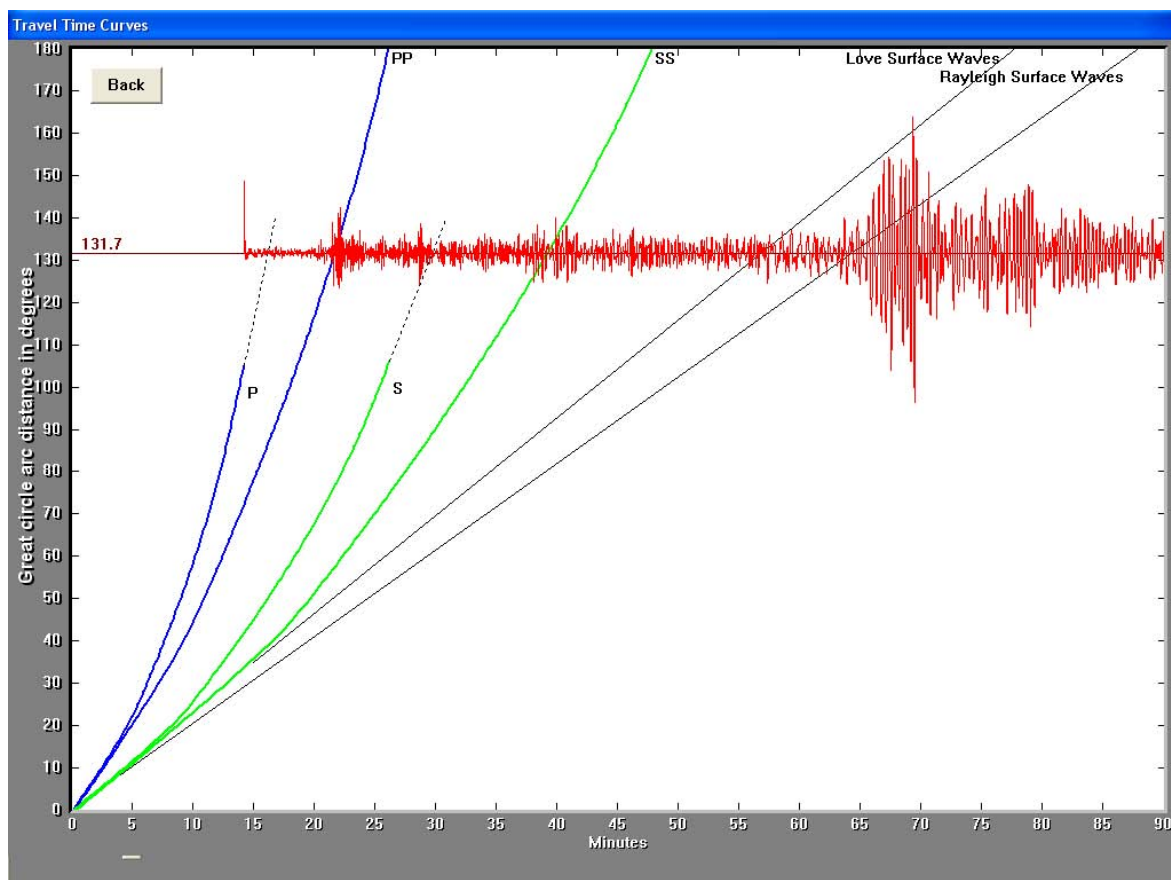
You can then move the seismogram around the screen using the mouse until your identified phases match the appropriate curves. In this case we can clearly see a PP phase and an SS phase. If these are aligned with the PP curve and the SS curve it is possible to read off the distance to the earthquake on the scale on the left. In this case it is 131 degrees.

TIMING OF DATA

Seismologists always use UTC time with which to label earthquakes. UTC or Coordinated Universal Time is what used to be called GMT or Greenwich Mean Time. This enables seismologists recording the same earthquake in different time zones not to get confused about what the event origin time was. AmaSeis logs data from the SEP Seismometer System labelled with the date and time as UTC times. It takes this information from your PC system clock; it is clever enough to be able to account for local time differences (e.g. summertime offsets and local offsets from UTC), which should be set up in your system already. You should be able to time the arrival of seismic waves from distant earthquakes at your school to within a second.

Accuracy

Left unattended PC system clocks are not very accurate and will quite quickly drift a few seconds or even minutes. For this reason, computers on a managed network usually have their clocks all synchronised together automatically and are often synchronised to a reference clock somewhere on the internet. Your system administrator should be able to tell you whether computers on your network are kept synchronised.

If you are unsure of your computer clock's accuracy then you can download and run a simple application which will automatically update your PC's system clock at regular intervals. A good application to use is AboutTime, available for free download at:
http://www.arachnoid.com/abouttime/

The program is simple to install and can be configured to update your PC system clock automatically (we recommend doing this about once per hour).
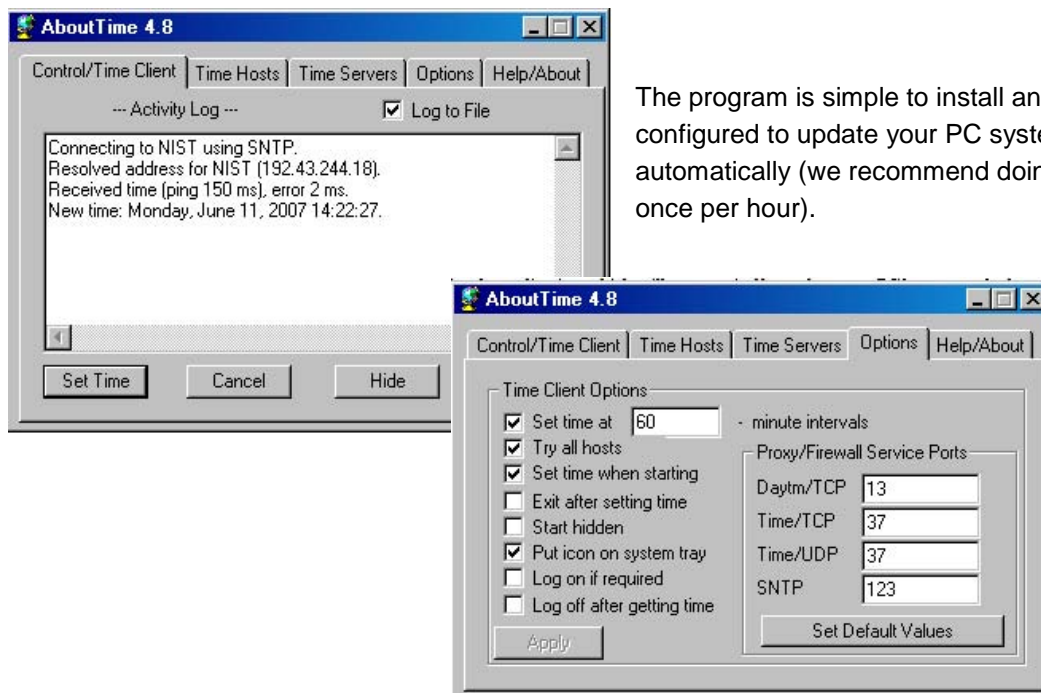
KEEPING LOGS

Station Log

It is good practice to keep a station log with your SEP seismometer to record all of the things that happen to the system. This can be as simple as a notebook that is kept by the instrument and updated every time something significant happens (e.g. a software update, moving the instrument, re-centering the sensor etc).

Date and Time (GMT)	Comment
25th July 2007 09:30	Setup SEP seismometer with 20second period and 0.7 damping in office J032 facing East.
1st August 10:30	Remove Seismometer for demonstration.
7th August 09:30	Replace seismometer in office J032 (Keyworth) period 22 seconds damping 0.7 facing East.
10th August 12:00	Replace seismometer cover with taped seams.
15th August	Earthquake detected.
1st September 10:00	New version of AmaSeis (v2.0) installed.
2nd September	Start uploading data to IRIS ftp site.
12th September	Series of massive earthquakes detected in Sumatra.

Event Log

It is also useful to create an event log to keep track of all the events that you have recorded on your instrument. This is best done with a spreadsheet that can be updated over time (you might want to delegate this task to a keen student or to set up a rota for 'duty seismologists' if you have a number of keen students).

APPENDIX 1: PRINCIPLE OF OPERATION

The seismometer detects horizontal (side-side) ground vibrations with an offset pendulum. Pendulum seismometers are sensitive to signals at or above their natural oscillation frequency, we are interested in detecting signals with frequencies (periods) of 1 Hz (1 second) for P waves, 0.5 Hz (2 seconds) for S waves and 0.05 - 0.1 Hz (10-20 seconds) for surface waves. The geometry of the suspension allows this pendulum to have a natural period of up to 20 seconds; a simple pendulum would need to be 100 m tall to have this period. When the ground beneath the seismometer moves, the seismometer mass will tend to stay where it is (due to its inertia). The relative motion between the seismometer mass and the seismometer frame is converted to a voltage with a magnet and a coil (the motion of a coil in a magnetic field produces a voltage proportional to the *velocity* of the relative motion).

For a simple pendulum of lengh l the natural period of oscillation T:

$$T = 2\pi\sqrt{l/g}$$

Where g is the acceleration due to gravity (9.8 m s^{-2})

For a pendulum of length 1m this gives T ~2 seconds (about the period of a pendulum in a grandfather clock). To design a simple pendulum with a natural period of 20 seconds we would need a pendulum length of ~100 m.

However if we adjust the suspension system to that of a 'garden gate' or 'Lehman pattern' where a horizontal boom rotates about a two-point suspension we can adjust the effective length of the resulting system by adjusting the angle of suspension. In this case the effective length of the pendulum is $l/sin(\alpha)$ so the natural period of the system T becomes:

$$T = 2\pi\sqrt{l/g\sin(\alpha)}$$

In this way it is relatively easy to design a seismometer with a reasonable sized boom (0.5 m) that has a natural period of 20 seconds, by slightly tilting the system with an angle of 0.3 degrees (this corresonds to tilting one end of the seismometer by ~2 mm).
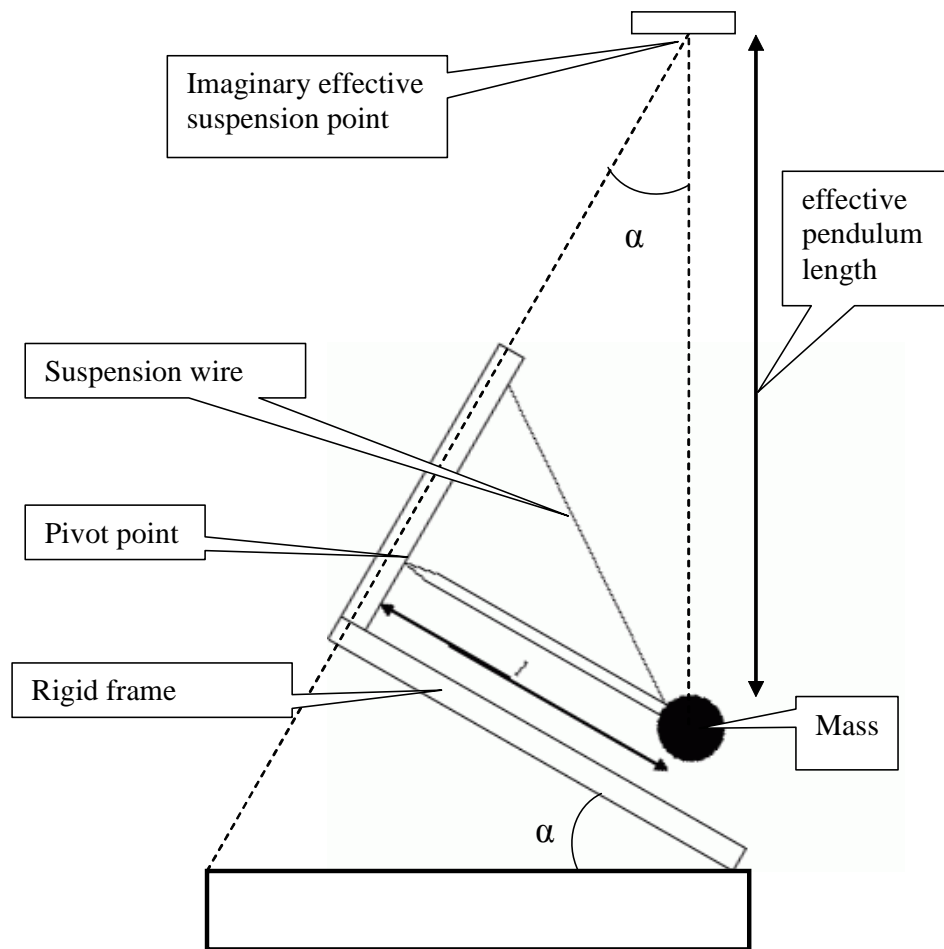
Left to its own devices a pendulum seismometer will oscillate at its natural frequency when disturbed. To avoid these natural oscillations the SEP Seismometer motion is damped with an eddy current magnetic damping system. A non-magnetic aluminium plate moves with the seismic mass inside a strong magnetic field. The motion of the conducting plate in the magnetic field generates eddy currents in the plate; these eddy currents in turn produce a secondary magnetic field with the opposite polarity to the applied magnetic field. These opposing magnetic fields cause a force that acts against the direction of motion of the plate. The strength of this 'damping force' is proportional to the velocity of the motion. The strength of this damping force can be adjusted by increasing or decreasing the area of the damping plate that is in the magnetic field.

APPENDIX 2: BACKGROUND NOISE

In a reasonable installation, with a suitable cover over the sensor, you should see a random looking signal displayed in AmaSeis similar to that shown (below left). Using an amplifier gain of x100, the background noise level should have a peak of about 500 counts and the spectrum should have peak noise level at a period of about 6 seconds (below right). This display can be obtained by selecting Control > Fourier Transform > Linear and then clicking on the 'vs period' button below the display. This 6-second 'microseismic' is not really noise but more like an ever-present uncorrelated background signal.
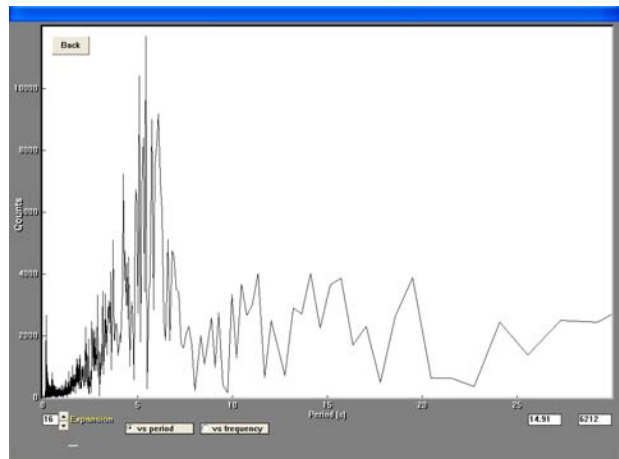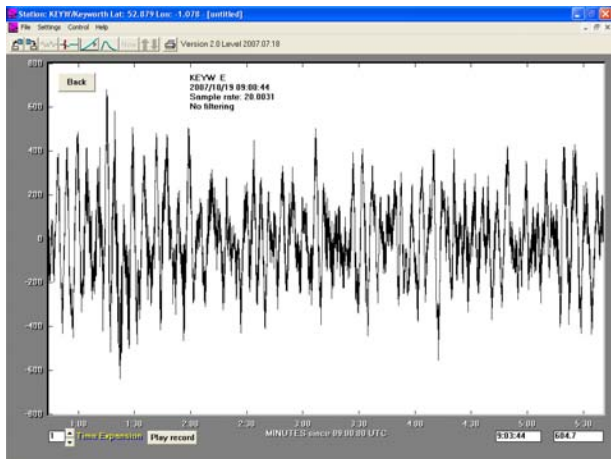
Without a cover over the seismometer, the noise signal at the same site will be 2-3 times greater (below left). The spectrum of an uncovered seismometer will have a peak in the noise spectrum in the region 10 - 20 seconds (below right). Unless you are recording the surface waves from a distant earthquake, this is caused by locally generated noise (being picked up through drafts and vibrations in the air).
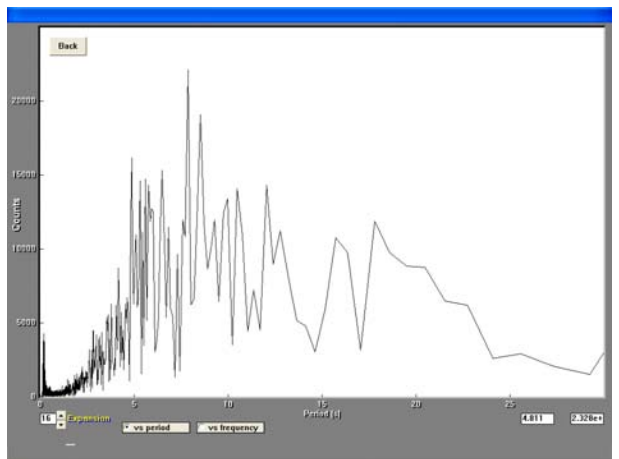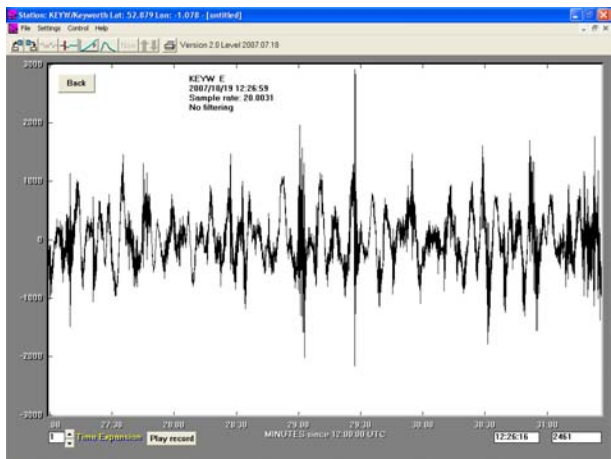
APPENDIX 3: AMASEIS ACROSS A NETWORK

AmaSeis has the ability to transmit and receive data automatically across a network. This enables you to monitor data from your SEP Seismometer System on any computer in your school's subnet or to automatically upload data from your school to an international database that is accessible to everyone.

Realtime data broadcasts across your school

```
[AS1]
Version=Version 2.0 Level 2007.07.18
Latitude=52.879
Longitude=-1.078
Elevation=100
BAUD=9600
COM=5
SampleRate=20
Gain=1
Component=E
StationName=Keyworth
NetworkID=EN
StationCode=KEYW
FileExtension=LPE
LinesPerHour=1
LinesPerScreen=24
DecimateFactor=1
DaysToRetainRecords=365
LowPassCutoff=1
LPNaturalFrequency=5.5
LPQ=0.5
LPPeriod=16
LowPassPeriod=10
LowPassSec=1
HighPassPeriod=20
EventHighPassPeriod=20
EventLowPassPeriod=6
EnableLowPass=1
EnableHighPass=0
HelicorderFilter=1
ZeroLevel=2048
InitSampleSeconds=5
BandPassLowCutoff=0
BandPassHighCutoff=2
CalibrationMass=0.0318
CalibrationDistance=10
MassOfArm=465.5
CenterOfGravity=28.8
mbAmplitude=100
MsAmplitude=100
mbLgAmplitude=100
mbPeriod=2
MsPeriod=20
mbLgPeriod=1
InstrumentResponse=100
GreatCircleArc=50
Depth=33
DataDirectory=Keyw\
SeismicWaves=c:\sw
GlitchRemoval=0
TCPPort=53760
TCPHostAddress=192.171.123.123
TCPRefreshSeconds=2
TCPClient=NO
TCPServer=YES
FTPAddr=
FTPUser=
FTPPW=
FTPUploadPath=
FTPDownloadPath=
FTPDaysToSave=3
FTPDownload=NO
LogFile=logfile.txt
CalibrationFile=Calibration.txt
Device=SEPUK1
```

If the PC that is connected to your SEP Seismometer System is also attached to your school intranet then you should be able to monitor the data being recorded on any PC in your school.

Edit the AS1.ini file using notepad in the folder c:/amaseis on the PC attached to the seismometer and make sure that the line:

> TCPServer=YES

is included. Your IT administrator should be able to tell you what the TCPHostAdress of this computer is (it is usually called the IP address). You can choose any TCP port number to broadcast data onto your network; however your network administrator might prefer you to use a number in the range 49152 through 65535 to avoid possible conflicts. Once set up as a server, AmaSeis will listen for data requests on the assigned port.

To access the data on a client computer you need to run AmaSeis on the client PC (anywhere on the network). Edit the AS1.ini file to have the same IP address and port number but make sure you have the line: TCPClient =YES.

```
TCPPort=53760
TCPHostAddress=192.171.123.123
TCPRefreshSeconds=2
TCPClient=YES
TCPServer=NO
```

A single server can support several clients at the same time (up to 6 maximum). If your school firewall permits, these could be off-site on the internet (usually firewalls will prevent this).

Automatically uploading data to IRIS using ftp

AmaSeis includes the ability to upload data automatically to an anonymous ftp site hosted by IRIS (the site of the global seismic database). This is the simplest and most straightforward method for sharing the data that you have recorded with other people around the world. In order to use these facilities you need to download a set of auxiliary programs *AmaSeisAuxSetup.exe* from the website:

http://www.geol.binghamton.edu/faculty/jones/AmaSeis.html

This will install two programs - *Upload* and *Stations*.

```
[AS1]
Version=Version 2.0 Level 2007.07.18
...

TCPPort=53760
TCPHostAddress=192.171.188.113
TCPRefreshSeconds=2
TCPClient=NO
TCPServer=YES
FTPAddr=ftp.iris.washington.edu
FTPUser=anonymous
FTPPW=youremail@isp.com
FTPUploadPath=pub/dropoff/amaseis
FTPDownloadPath=
FTPDaysToSave=3
FTPDownload=NO
LogFile=logfile.txt
CalibrationFile=Calibration.txt
Device=SEPUK1
```

Edit the AS1.ini file on the computer attached to your seismometer to include the following lines. Once AmaSeis is running and recording data, you should then run the application called *Upload*:

This will now start uploading data files to the IRIS ftp site. Files are uploaded once they are complete (at the end of each hour). A program on the IRIS server then checks to see if they are valid sac format data files before moving them to a publicly accessible directory (/pub/amaseis).
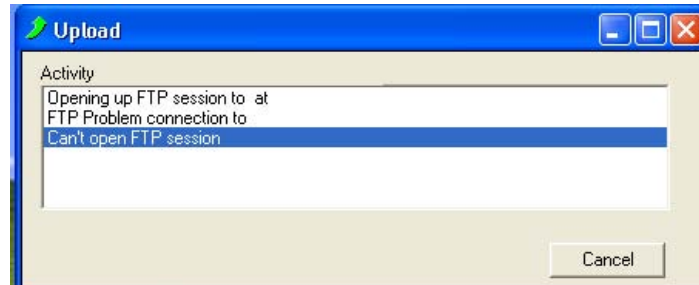
FTP directory /pub/amaseis/ at ftp.iris.washington.edu

To view this FTP site in Windows Explorer, click **Page**, and then click **Open FTP Site in Windows Explorer**.

Up to higher level directory

```
06/27/2007 10:39AM       Directory   CHOR
07/17/2007 06:24PM       Directory   E1OR
07/20/2007 09:51PM       Directory   E2OR
07/30/2007 03:01PM       Directory   KEYW
06/22/2007 01:54PM       Directory   SBNY
06/19/2007 06:57PM       Directory   TEST
09/05/2007 08:00PM       Directory   WLIN
09/24/2007 07:46AM          21,487   amaseiscron.log
```

APPENDIX 4: ACCESSING DATA FROM THE IRIS FTP SITE

The program Stations.exe from the AmaSeis auxiliary setup (see page 24) is a GUI (graphical user interface) that allows users to download data from the iris ftp site. The program will show a map of the world with available stations shown as red triangles. When you click on one of the red triangles AmaSeis will be launched and start downloading data from the iris ftp server for that station. Please note that this program requires access permission to anonymous ftp servers through your computer or site firewall.
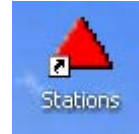

```
<?xml version="1.0"?>
<file name="IRISEdStations.xml"/>
<update date="2007-04-27 00:22:07"/>
<format version="0.1"/>
<IRISEdStations>
<station
  name="BGS Keyworth"
  code="KEYW"
  latitude="52.879"
  longitude="-1.078"
  ftp_addr="ftp.iris.washington.edu"
  ftp_user="ftp"
  ftp_pw="p.denton@bgs.ac.uk"
  ftp_path="pub/amaseis"
 />
</IRISEdStations>
```

The program *Stations* reads information about station locations from a data file called IRISEdStations.XML in the AmaSeis program folder. Additional stations can be added by simply editing this file in Notepad.

An up-to-date version of this file will be available for download through the British Geological Survey (BGS) *School Seismology website* (www.bgs.ac.uk/schoolseismology).

BGS are setting up a system for automatically accessing data from this anonymous ftp server and making it available through the data pages of this website.

APPENDIX 5: MAGNITUDE CALCULATIONS

It is possible to use data from the SEP seismometer system to make estimates of the magnitude of the earthquake that you have recorded. Seismologists can only ever make estimates of the actual magnitude of an earthquake by measuring the effects of the earthquake on instruments located at some distance from the event.
(See web resource at: www.bgs.ac.uk/education/school_seismology/supportdocs.html)

These estimates will vary from station to station and the final agreed magnitude is an average of many stations' calculations.

Example

The USGS reported an earthquake on 30 SEP 2007 02:08:29 SOUTH OF MARIANA ISLANDS. The email alert that was sent out about this event (90 minutes after the origin time) reported its magnitude as Mw=7.0. On the USGS website the earthquake is given an 'official' magnitude of 6.9, calculated as a weighted average of 373 individual measurements from different stations around the world. These details for recent events can be found at:

http://earthquake.usgs.gov/eqcenter/recenteqsww/Quakes/quakes_all.php

Click on the event you are interested in then the "Scientific and Technical" tab and the Phases link.

Station Phase data for event 30 SEP 2007 02:08:29 (USGS website)

Station	distance	amp(μm)	period(sec)	Ms
DGAR	75	23	20	6.50
LVZ	88.1	44	20	6.90
CBKS	101.9	86	21	7.20
ISP	102.8	25	21	6.70
EYMN	103	120	21	7.40
BORG	104.3	21	20	6.70
COWI	105.3	130	21	7.40
KVTX	107.8	96	22	7.30
CCM	108.2	60	21	7.10
HDIL	108.2	85	21	7.30
ESK	109.4	41	21	7.00
TZTN	114.2	68	21	7.20
BRAL	114.7	88	22	7.30
LBNH	115.7	86	21	7.30
NHSC	118.5	61	20	7.20
DWPF	120.4	71	20	7.30
SFS	126.3	67	21	7.30
RTC	128.6	21	22	6.80
CMLA	131.3	24	22	6.90
			Average	7.09
			Max	7.40
			Min	6.50

The average surface wave magnitude of these stations is reported as Ms=7.1, the average body wave magnitude is given as Mb=6.4

This table shows data from some of the stations used in the calculation of Ms by the USGS. Note that there is considerable variation in the magnitude values calculated for different stations (for this event they ranged from Ms=6.5 to Ms=7.4). Station ESK is the only station in the UK routinely used for magnitude calculations by the USGS (Eskdalemuir in Scotland).

The definitive magnitude for an earthquake is not determined until data from all available sources are analysed. These calculations are determined by the International Seismological Commission (www.isc.ac.uk) based near Oxford in the UK. The definite earthquake bulletins that they publish contain the most accurate possible estimates of event location and magnitude. However, these are not usually available until 2 years after the event.

Magnitude calculations using a SEP seismometer

The best estimate of the magnitude of an event that can be made with a SEP seismometer system is using the Surface wave magnitude formula (Ms). (For a definitive list of magnitude formulae see: http://www.isc.ac.uk/doc/analysis/2006p03/magletter.html)

$$Ms = \log(Vmax / 2\pi) + 1.66 \log\Delta + 3.3$$
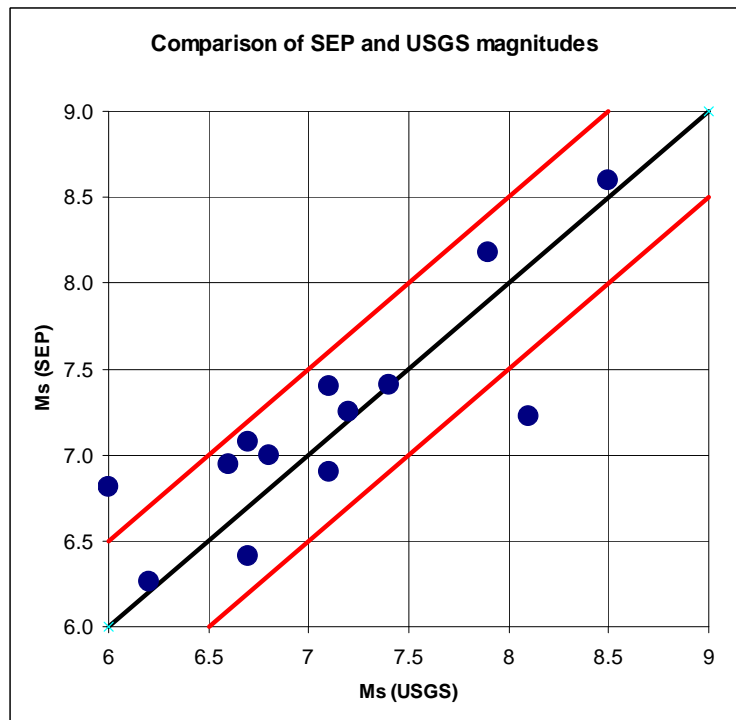
Vmax is the peak velocity amplitude at period ~20 second (μm/sec)
Δ is the distance from the earthquake (degrees)
Valid for events shallower than 80 km and in the distance range $2° \leq \Delta \leq 160°$.

Vmax can be estimated by measuring the peak amplitude of the surface waves recorded by the SEP seismometer (with data filtered with a 10 second low-pass filter). You can determine the sensitivity of your seismometer empirically by monitoring many event magnitudes. For an amplifier set to x100 gain you should get a response factor of approx 50 counts/(μm/sec). Using this response factor the SEP seismometer located at Keyworth (station KEYW) gave a magnitude for the Marianas Islands event discussed earlier of Ms=6.9; this is well within the range of values calculated by professional seismic observatories around the world for this event (the range was 6.5-7.4 for this event).

Note this formula was originally defined for vertical response seismometers so we are introducing another source of error by using only horizontal component data; the actual error will depend upon the relative orientation of the seismometer to the source fault plane. However the range of results obtained using this empirical calibration is within +/- 0.5 magnitude units, which is the typical range of magnitude calculations for an event from single stations around the world.

Event Log for station KEYW at BGS offices Keyworth

$Ms=\log(Vmax/2\pi) +1.66\log\Delta + 3.3$ where Vmax is peak velocity amplitude at period ~20 second

Year	Month	Day	hhmmss	Lat	Lon	Ms	Depth	ΔKeyw	SW peak (counts)	Vmax	50 amp/Vmax	counts/µm/sec Msep
2007	3	13	025904.40	26.26	110.54	6	26	79	720	2.23	323	6.8
2007	4	1	203956.38	-8.46	157.04	8.1	10	131	800	121.14	7	7.2
2007	4	3	033507.28	36.45	70.69	6.2	222	51	150	7.30	21	
2007	6	24	002518.40	-55.65	-2.63	6.5	10	108		4.19	0	
2007	6	28	025209.65	-7.97	154.63	6.7	10	130	580	4.88	119	7.1
2007	8	15	202211.15	50.33	-177.55	6.4	9	82		5.26	0	
2007	8	15	234057.90	-13.39	-76.6	8	39	91		176.18	0	
2007	9	2	010518.42	-11.58	165.77	7.2	35	136	800	14.33	56	7.2
2007	9	6	175126.29	24.31	122.25	6.6	53	88		7.42	0	
2007	9	10	014911.24	2.96	-78.04	6.8	9	79	1100	14.06	78	7.0
2007	9	12	111026.62	-4.52	101.37	8.5	34	100	30000	476.39	63	8.6
2007	9	12	234904.84	-2.54	100.93	7.9	35	100	11400	119.66	95	8.2
2007	9	13	033528.38	-2.16	99.59	7.1	22	100	1880	18.97	99	7.4
2007	9	20	083114.00	-2.02	100.14	6.7	30	98	200	7.81	26	6.4
2007	9	28	133858.00	21.98	142.68	7.4	261	99	938	38.48	24	
2007	9	30	020829.00	10.49	145.68	6.9	10	110	515	10.22	50	6.9
2007	9	30	052334.00	-49.39	163.87	7.4	10	170	800	15.68	51	7.4
2007	9	30	094749.00	-49.41	163.26	6.6	10	170	275	2.49	111	6.9
2007	10	2	180001.00	54.64	-161.8	6.2	48	72	240	4.12	58	6.3