

**How to teach natural hazards in school:
raising awareness on seismic hazard**

In the frame of the Naras EU-project (Natural risk assessment) and in collaboration with Eduseis (www.eduseis.net), an educational "cook book" has been produced for schools in order to increase knowledge related to earthquakes and seismology. Teachers and pupils will be able to learn more about science in this field and increase their awareness in disaster reduction through simple exercises and activities.



**How to teach natural hazards in school:
Raising awareness on
earthquake hazard**



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How to teach natural hazards in school: Raising awareness on earthquake hazard

**Educational outreach
developed by the EduSeis European project
in the frame of the NaRAs EU project**

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Foreword

European research in the field of natural hazards has been active since the late 1980s. It has contributed to increase our understanding of the processes and mechanisms and our overall knowledge related to hazard, vulnerability and risk of key hazards affecting Europe and the world.

Communities around the world are facing natural hazards, for some this is a daily threat to both safety and livelihood. It is therefore important to have a holistic approach to natural hazards developing not only disaster response systems but considering disaster risk preparedness and mitigation as an integral part of sustainable development. The international effort aiming at natural disaster reduction is certainly contributing to this goal.

Improving public awareness and education of the population is an essential part of mitigation of natural risks. Starting this effort at the level of schools will certainly be a way to increase the chances of success.

This was one of the aims of the European NARAS project (Natural risk assessment) when it started its collaboration with the ongoing Eduseis effort (Educational seismology project) which is an educational tool for training and increasing awareness of seismic risk. It connects a number of European schools, scientific museums and research institutes in a prototype of a seismic network, made of high technology and low cost components.

The goal of this publication is to disseminate scientific information related to earthquakes in a practical and user-friendly form by making use of this prototype seismic network. Educational activities have been collected in a simple "cookbook" (manual of activities) with the aim to diffuse an educational and formative experience at a large scale.

We do hope that teachers and pupils will find this document useful and that this effort to translate scientific knowledge into a learning process will enable an increased awareness of earthquake hazard and contribute to improved protection of lives.

Elisabeth Lipiatou and Denis Peter
Climate Change and Environmental Risks Unit
Directorate General for Research



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EduSeis and NaRAs project

Awareness and Education of European population, a key element for mitigation of natural risks

In Europe, there is a strong concern about natural hazards as well as natural risks. As people may travel all around the world, awareness of population should be increased not only for natural risks in Europe but also for natural risks we may unlikely encounter in other areas.

As shown dramatically by the 26 December 2004 mega-event which has generated an exceptional tsunami, protection of the population depends on the reaction of each of us and, therefore, relies strongly on our education. Adequate behaviour in front of exceptional events should be undertaken by each of us at any moment without any help.

Earthquakes may happen in Europe, especially in area around the Mediterranean Alpin Arc from Portugal towards Greece. They may help us bring awareness by their regular occurrence if they are adequately observed.

Mitigation of these quite exceptional natural risks may go through prevention which is a necessary step for our society whatever are improvements in sophisticated warning or early warning systems. Once alert has been launched towards the population, before the arrival of well-trained rescue teams, we are on our own for very precious minutes in order to save our life and the life of others around us.

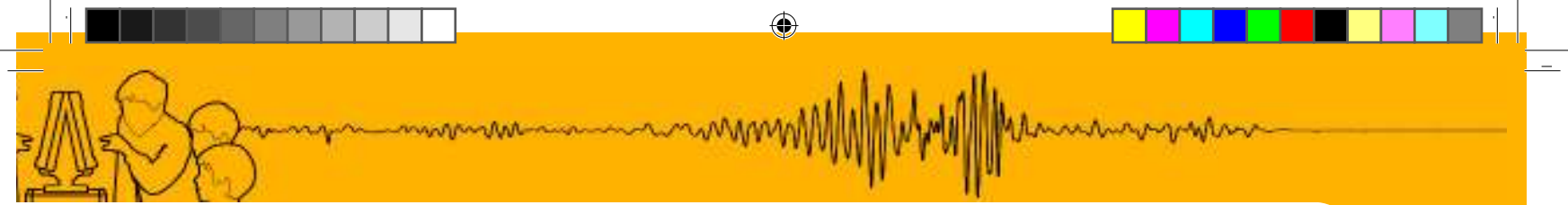
Better estimation of natural hazard and better monitoring of our natural environment as well as better management of territory are not enough. Information and education are two essential ingredients in any politics related to mitigation of natural hazards.

Creating and developing a seismological network around the world with an educative purpose has been a long-standing goal which has been supported by different funds often quite local ones related to local political concerns for young people education. One must underline an exception with the Specific Support Actions NaRAs of the European Union. This programme has allowed the transformation of local actions into widespread initiatives and has permitted us concrete realisation as this document for precise training of young students.

Actually, the installation of seismometers in schools in different areas of Europe has given the necessary impulsion for students by a scientific approach for better development of activities around the hazard knowledge, the real time manipulation of information and scientific databases as well as the better understanding of related matters on risks and territory managements.

Therefore, by this long-standing education programme with the driving motivation of building a seismic network across different scholar communities in Europe, teaching Earth Sciences now integrates the difficult problematic of vulnerability in our urban society which becomes more and more dependent of any variation coming either from our natural environment or our industrial environment.

Best practices all around these European countries have been shared by teachers of different countries and various experiences have shown the richness of such sharing which has been performed during the NaRAs programme.



Toolkit for laboratory experiments by students: it has been designed during the NaRAs project for the illustration of different effect of seismic shaking.

A long-term collect of different activities has been undertaken and finalized through this cookbook of proposed exercises with the help of the programme NaRAs. The SSA NaRAs has been the melting pot of teachers for sharing their experiences and for providing this book with combined exercises. The result is an already widespread cookbook which illustrates how it is possible, with the help of seismic data collected in schools, to tackle quite sophisticated scientific topics in a simple and pragmatic way during teaching and training.

The "sensors" topic is an essential step. Measurements through a sensor (for example of the ground motion with a universal time) could be explored from sensors of the seismic station or from sensors developed by students. Various aspects of the basic scientific background are tackled as the frequency, the bandwidth, the fidelity, the repeatability, the robustness related to the often linear oscillator behind the sensor.

The "data" topic is the necessary next step. The analysis of recorded signals leads to various investigations: work on waves which are a key notion in our society as radio, TV, internet are using them intensively. Travel times, wave speed, localization through triangulation are typical features one student can easily master without going into sophisticated mathematical tools.



The "tectonic" topic is as well very rich in various activities. Numerous kits have been proposed and realized by students. These practical exercises will introduce abstract notion as seismic cycle, stress building, friction phenomena and energy release among others.

The "Earth" topic is obviously a central point for Natural Sciences teaching with the possibility of geographical mapping through the presentation of data collected among schools, the discussion of the seismic hazard either at the global scale or at the local scale, the presentation of different seismic signatures as Benioff planes or Moho discontinuity. Finally, these activities illustrate how we know the internal structure of the Earth.

The "risk" or "hazard" topic comes naturally after these different speculations or analysis. From seismic records, students will illustrate through practical constructions the notion of intensity, the building resonance, the paraseismic rules of constructions and the induced effects of a tsunami on coastal zones. With many national initiatives, this topic will increase more and more its importance during educational trainings.

All these examples of simple activities, which could be worked out by students, have be collected and brought in this single cookbook, thanks to the SSA NaRAs programme. This collaborative work which has started ten years ago could illustrate the conjugated efforts of researchers and teachers for a better education and awareness of the risk culture especially in young populations.

Jean-Luc Bérenguer
Jean Virieux





Preface

In the last few decades the economic and social losses caused by large earthquakes have increased the studies on the seismic risk with the goal to develop new strategies in order to mitigate the destructive effects of such events. Although the prediction of seismic events today is not yet possible, much is known about the nature of earthquakes and the tectonic processes responsible for them.

Earthquakes primarily occur in active regions where the tectonic plates converge, diverge or slide past each other. Fortunately, the largest earthquakes are infrequent and some of these caused no fatalities because of their remote location or deep focal depth. But the growth of population and the expand of urban agglomerations in areas of high vulnerability have led to undertake many actions in order to avoid or to reduce their risk. Although the statistics are often imprecise, the damages and societal consequences of large earthquakes in developing regions, can be enormous. Estimates are that the 1988 Spitak (Armenia) shock killed 25000 people and that the 2003 Bam earthquake (Iran) caused about 30000 deaths. More than 280000 deaths for the great earthquake that occurred near the coast of NW Sumatra on December 26, 2004. On average during the past century earthquakes have caused about 11500 deaths per year determining also important changes to society. Most earthquake-related deaths result from the activation of secondary events like collapse of buildings, landslides and so on. To try to mitigate seismic risks the seismology, defined like the study of earthquakes and associated phenomena, is the major tool for earthquake hazard assessment. At the same time a better knowledge and management of our natural environment as well as better awareness of population should be increased through a politics of prevention related to mitigation of seismic hazards. In this framework information and education are fundamental ingredients into a program of spread of the risk culture.

EduSeis is an educational tool for training and increasing awareness on the seismic risk which involved high schools, scientific museums and research institutes in different European countries, in the consolidation of a prototype of seismic network, made of high technology and low cost component. The innovation of the EduSeis project is not only the implementation of the technological tools but also in the diffusion of scientific information and data in a user-friendly form. This is achieved developing educational activities linked with seismology and Earth structure analysis. These activities have been collected in a simple "cookbook" (manual of activities) with the aim to diffuse our educational and formative experience at a large scale.



The EduSeis Project

The Educational Seismology Project (EduSeis) is a research and experimentation project involving research centres, Universities, scientific museums and schools in the consolidation and maintenance of a prototype of a seismographic network, made of high technology and low cost components. It is used as a permanent infrastructure with the aim at promoting the Earth Science (especially seismology and geophysics) and to increase the awareness on seismic risk at the level of high schools and of large public. A network of digital seismographs installed in a number of high schools in different European countries (France, Italy, Portugal and Germany), make available in classroom data and tools which were only used in research laboratories.

Through regional and teleseismic earthquakes data processing, the students take an active part in monitoring of the territory, and recordings of strong seismic events, which allows them to understand the dynamic evolution of the Earth and to have a direct perception of the seismic hazard of the region where they live.

Using specific tools of signal processing, the students can measure the time and space variability of natural phenomena and learn to observe and compare the occurrence of the same natural phenomenon at different sites. In this way the pupils are active participants rather than passive consumers in the study of seismological phenomena.



The analysis of seismograms is, moreover, very interesting because involves many fields like physics, mathematics, geography, geology, technology and social science.

The key action of the EduSeis project is to bring people closer to science and technology through an integrated system of science communication based on scientific personnel with experience in outreach, the use of innovative educational devices, the availability of suitable facilities for experimentation and the possibility of sharing educational experience through the participation in national or international science centres network.

The project has many educational, scientific and social aims. These objectives are being carried out through the experimentation of new methodologies for scientific learning using advanced scientific equipment and real laboratory experiences aided and maintained by specialized technical staff.

Educational objectives

An important task of the project is to train students and teachers to make analysis and interpretation of seismological data using the EduSeis network data-base. For this purpose modules and didactic activities on seismology and other disciplines, like Physics, Mathematics, Earth Sciences and Computer Sciences, have been designed and tested using informatics and web-oriented tools. Teachers and students involved in the experimentation can test the practicability, the contents and the didactic value of the activities.



In addition, the project offers the opportunity for students and researchers from different countries to exchange programs and ideas through the use of modern computers based on systems of archives, access, consultation and promulgation of the information represented by the Internet network.

Scientific and technological objective

A network of digital seismographs has been installed in a number of high schools, in Italy, France, Germany and Portugal.

The maintenance and updating of the seismic stations has demanded the development of specific hardware and software systems able to run in heterogeneous site conditions and allow remote data retrieval and station control (acquisition system, remote control, automatic retrieve and archive of the seismic data, EduSeis database construction, analysis and processing of seismic signals ...). At the same time the experimentation of the educational activities has allowed the transfer to teachers and students of the necessary competencies to manage the seismic stations installed in the schools. The wide range of seismic data recorded are collected in an earthquake waveform archive, easily accessible from the web site by students, teachers and general public and are used for educational purpose.

The exchange of scientific information and data between the schools, the museums and the centres of research inside of the European network is realized by modern and automate systems of archives, access, consultation and promulgation of the information.

Social objectives

Although in Europe and, in particular in the Mediterranean area, the risk of strong earthquakes exists, the politics of information and awakening to the seismic prevention are still insufficient in comparison with analogous initiatives undertaken in other seismic regions in the world (such as for example Japan, Western United States). In this sense, the EduSeis project has a remarkable impact on the prevention of the seismic risk. This effect is achieved involving the high schools in management of seismic network and the creation of a dense network of seismic "observatories" that can increase the data available for research in the field of Earth Science. These seismic "observatories" will be extremely interesting and useful to the social and scientific community. In synthesis the project represents an effective instrument for informing and creating awareness about the seismic risk, to experiment the efficacy of scientific communication and increase the direct involving of schools and general public.

This book comes from the collective job of teachers, researchers and didactic specialists to the aim to promote the scientific culture and the education to seismic risk. The book presents the didactic activities tested in the classes that have been involved in the Eduseis project, in order to spread our educational and formative experience at larger-scale.



EduSeis network

The EduSeis network (Figure 1) consist of a standard personal computer equipped with an A/D 24 bit card, broad-band sensors and GPS clock. The sensor is preferably deployed at a ground or underground level while the acquisition PC is hosted in the informatics lab. All the elements of the seismic station are especially designed for educational purposes and can be operated independently by the students and teachers themselves.

The broad-band sensor allows the recording of both local and teleseismic seismic phenomena. The observation of local earthquake records stimulates interest in the origin and distribution of regional seismicity as well as the understanding of earthquake causative mechanisms. Teleseismic observations introduce the students to the global Earth structure through the study of the propagation of seismic wave inside the planet. Since 2001, EduSeis stations host the new Java software IRAE (Internet Remote Acquisition Engine) developed by AGE CODAGIS Sarl for seismological data acquisition purposes using intranet and/or Internet networks. The software is based on a communication system between stations and central PC. After the data analysis and processing, the best quality data from interesting events is selected and made available on the EduSeis web site. The database is organized both by event and by date. The seismic records are available to download (SAC format) and can be viewed and processed directly on the web in an interactive way using the software SeisGram written by A. Lomax, Geoazur, Nice (www.alomax.net).

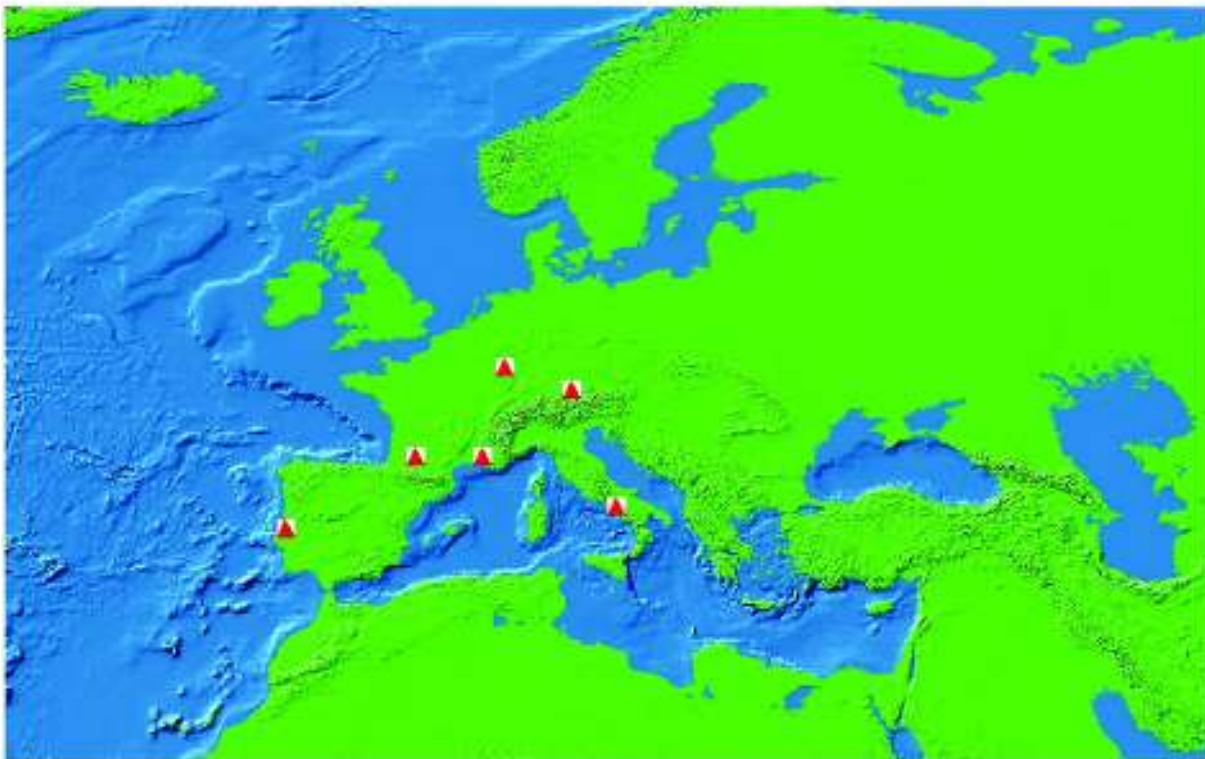
Thus, the teaching staff, has developed educational activities linked with seismology and Earth structure analysis. Signal analysis, earthquake location and mapping tools developed by Anthony Lomax (www.alomax.net) have made many of the basic procedures easier for the students. In the classroom, many things are done both offline and online.

Collaboration between teachers of different fields is very important to emphasize different aspects of seismology and seismograms. All involved people-students, teachers, and researchers- interact in order to develop more applications in a wide range of fields (mathematics, physics, history, geography, geology and so on).

The educative activities can be recovered both on the web site and in this "cookbook".



www.eduseis.net



Na.R.As



 **Geophysikalisches Institut
der Universität Karlsruhe**

Figure 1.



Links

in France

aster.unice.fr
www.edusismo.org
geoazur.unice.fr

French Riviera Schools Network
French Schools Network
Researcher Center - Simology Sophia Antipolis

in Italy

eduseis.na.infn.it
www.edusism.it
www.rissclab.unina.it
www.cittadellascienza.it

The EduSeis Project in Italy supported by Civil Protection
Web site of Liceo Copernico Naples
Sismology Centre of University Federico II Naples
Website of the Città della Scienza Naples

in Portugal

atelier.uarte.mct.pt
www.igidl.ul.pt

Web site of Escola Secundária de Odivelas
Istituto Geofísico do Infante D. Luis Lisbon

in Germany

www.copernicus-gymnasium.de/eduseis
www-gpi.physik.uni-karlsruhe.de

Web site of Copernicus Gymnasium Philippsburg
Web site of the geophysics institute Karlsruhe



Educational Activities

The educational activities proposed in this book have been structured as simple exercises which contain the necessary steps to complete the tasks.

These activities have been achieved through a participatory methodology aimed to involve a wide range of experts in different fields as seismological research, seismic hazard assessment, seismic signal processing, mathematics and physics.

The topics considered, in fact, allow to measure the main parameters related to an earthquake: magnitude, localisation of the epicentre, visualisation of the different seismic waves passing through the Planet and so on.

These educational proposals, moreover, can be performed both in classrooms and in scientific museums.

The main objective of the "cookbook" is to diffuse the experience of EduSeis with the specific objective to raise awareness on seismic hazards to pupils and their families through a new and innovative scientific tool.



1. Epicentre

Theme: Data Analysis

Objectives: Location of the epicentre of a local earthquake using a graphical method

Keywords: Seismogram, P Wave, S Wave, Epicentre

Fields of work: Natural Sciences, Mathematics

Author: Sylvie Buray, Centre International de Valbonne, France – sylvie.by@infonie.fr

What information can be extracted from seismograms?

Pupils analyze the seismic signals recorded by the EduSeis network for a local event, in order to determine where the earthquake occurred.

1st step

Selection of a local event from the EduSeis database It is necessary to choose an earthquake recorded by 3 stations at least. It may be useful to discuss with the pupils about the number of recordings we need to locate the epicentre.

2nd step

Determination of the epicentre-station distances.

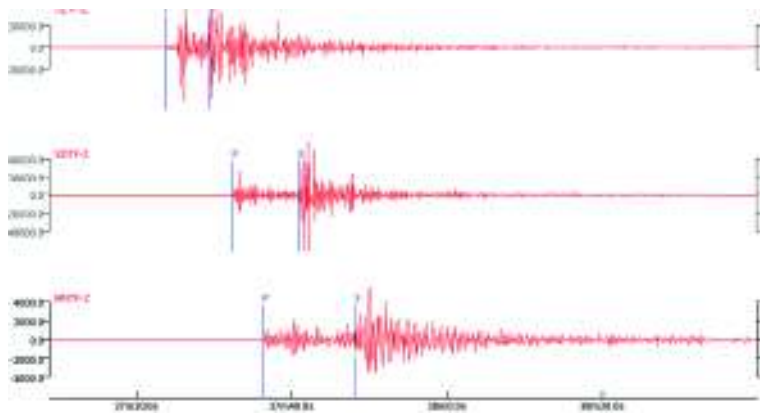
P wave has to be picked for each station: a first hypothesis concerning the event location may be proposed. Then, S wave time are picked and the delays between P wave and S wave are calculated for all the stations. Using an hodochrone, the distances can be determined.

3rd step

Event location.

On the EduSeis website, graphical methods are available to perform epicentre location online. The circles method is used in this exercise. For each station, a circle is plotted. The centre of that circle is the station, its radius is the calculated distance. The circles intersection corresponds to the epicentre. At this point it may be useful to confront the result with the information given by seismological centres.

More: It may be interesting to plot some regional events on a geological map to retrieve active faults, or to perform that event location with different methods (bisectors and hyperbola for instance).



Using the seismic signal analysis software available on the web site, P wave and S wave times are picked for each station.

Figure 1.

Using the graph in figure 2, it is possible to calculate the epicentral distance from the P-S time delay.

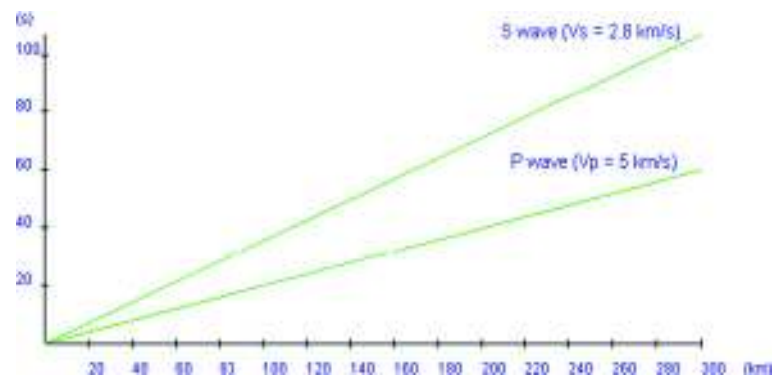
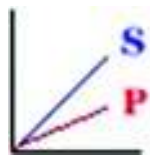


Figure 2.

On the web site, circles can be plotted and event location can be achieved.

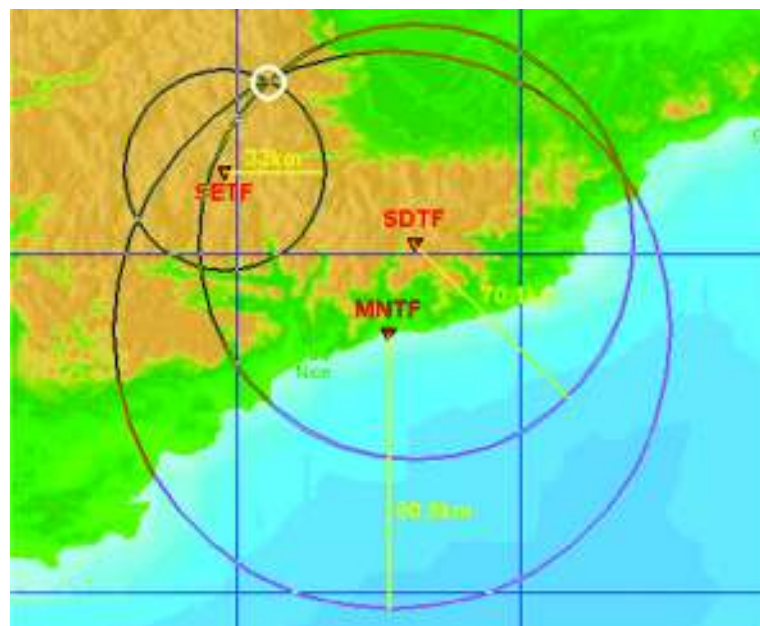


Figure 3.



2. Origin Time

Theme: Data Analysis

Objectives: Determine the origin time of a local event from seismogram analysis

Keywords: Seismogram, P Wave, S Wave, Hodochrone

Fields of work: Natural Sciences, Mathematics

Author: Thomas Picq, Centre International de Valbonne, France – tpicq@mail.civfrance.com

From the seismic signals recorded by several stations for a local event, we will demonstrate that the seismic waves velocity in the Earth crust is constant. The origin time will be determined, and P wave and S wave velocities will be calculated. For this exercise, we need to know the event location, to calculate station epicentre distances.

1st step

Select a regional earthquake from the web site database. To perform this exercise, four significant recordings of that event are needed. Stations should be located at various distances from the epicentre.

2nd step

Using a seismic analysis software, pupils pick P wave and S wave arrival times for each signal.

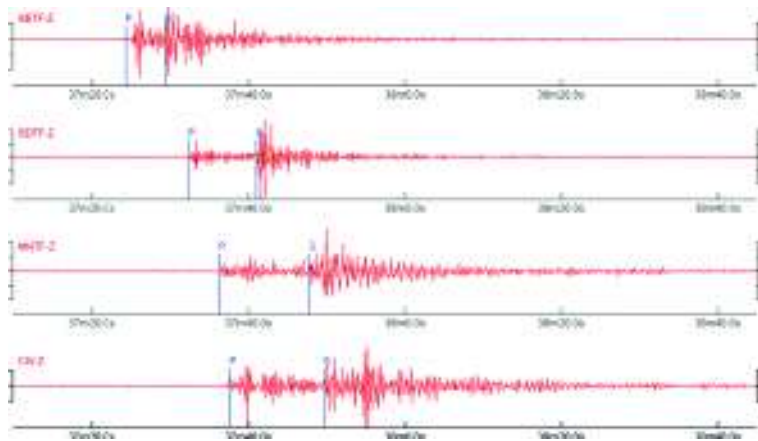
3rd step

A graphic is constructed with station epicentre distances for X coordinates, and arrival times for Y coordinates, for each station. This graphic is called hodochrone.

4th step

Pupils are invited to analyze the result they have obtained. They extract much information from these curves: origin time, P wave velocity, S wave velocity. At this point, it may be useful to confront these values with data given by seismological centres.

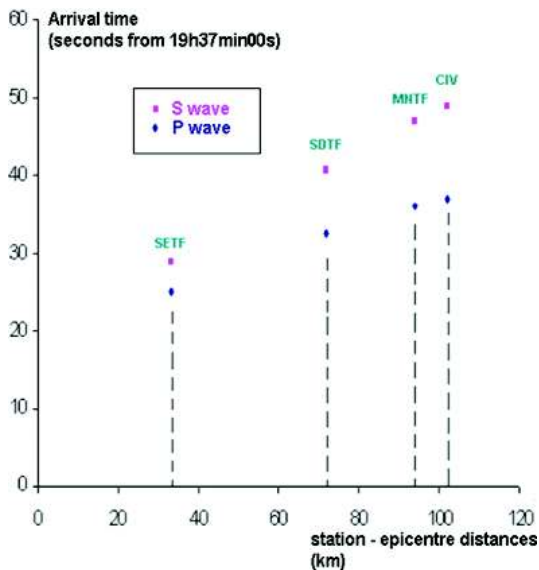
More: That experiment may be realised for other events and it would be interesting to compare the propagation velocities we obtain in the same area or in different regions.



Document 1
 Selected event: 01/07/2001 in
 Barcelonnette (Southern Alps, France)

Lat (epicentre) = 44.560°
 Long (epicentre) = 6.980°
 Four recordings are provided :
 SETF, SDTF, MNTF and CIV.
 These stations belong to the Aster06
 network (Alpes Maritimes, France).

Figure 1.

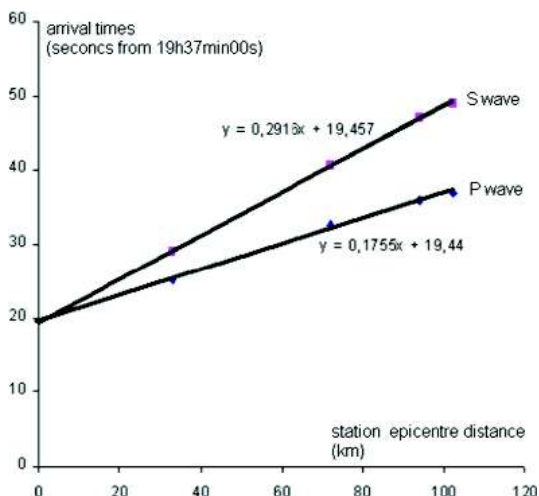


STATION	T(P) in s	T(S) in s	DIST. in km
SETF	25	29	
SDTF	32,6	40,6	
MNTF	36	47	
CIV	37	49	

time from 19h37min

Figure 2.

Document 2
 Using a spreadsheet, P waves and S waves arrival times
 are plotted on the same graphic, for all the stations.



Conclusions
 P wave points are aligned, S wave points are aligned
 too: seismic velocities in the Earth crust are constant.
 P wave and S wave lines intersect the "0 km" axis at
 the origin time: 19h37min19s.
 P wave velocity corresponds to the inverse slope of
 the P wave line: $v_p = 5.7$ km/s. In the same way, $v_s = 3.4$ km/s.
 In comparing the results we have obtained with the
 information given by seismological agencies, we observe
 that they are satisfying: $T_0 = 19h37min20s$.

Figure 3.

3. Plotting the Seismicity

Theme: Earth

Objectives: Represent the earthquakes location around the world

Keywords: Seismic Risk, Tectonic Plates Boundaries

Fields of work: Natural Sciences

Author: Jean-Luc Berenguer, Centre International de Valbonne, France – jlbereng@ac-nice.fr

Strong earthquakes occurred on some geographical areas frequently, while they don't seem to affect some other regions. We propose to determine the regions of the world affected by many strong events, from the catalogues of events provided by the seismological agencies.

1st step

Pupils download an events catalogue provided by seismological agencies, for a whole year. Each earthquake is defined by the following parameters: date, origin time, latitude, longitude, depth and magnitude. To explain how to read this document, it may be useful to extract some significant events of the year.

2nd step

After that first explanation, a map will be construct where each event will be located. To perform that step, we will utilize a spreadsheet graphical tool, where the latitude and longitude columns will be used for the events plotting. The epicentres are located on some specific areas, that delimit the seismic area on the Earth surface.

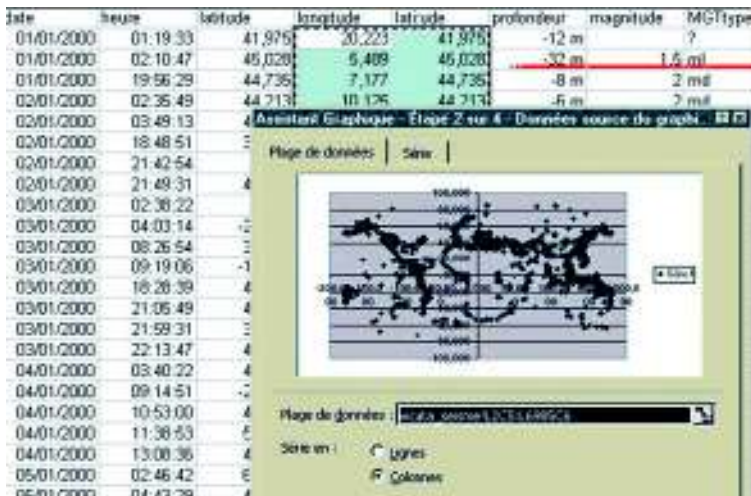
More: It may be interesting to perform that work on a regional scale area or to confront the results with a GPS study of tectonic plates displacements.

Document 1

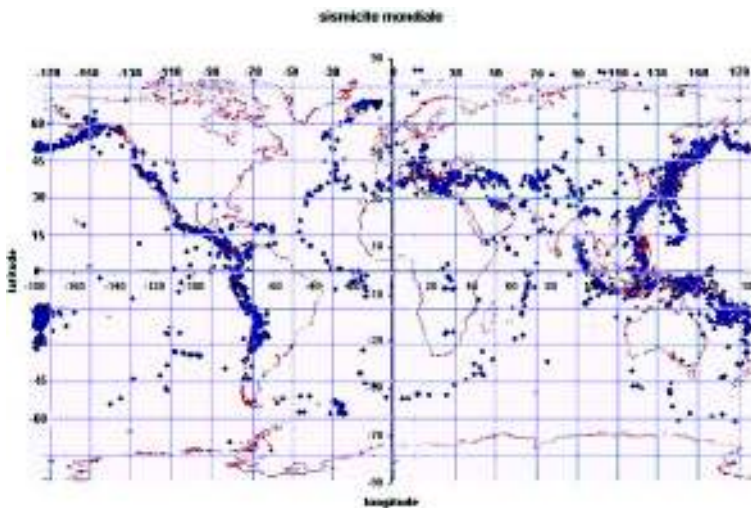
Download events of a catalogue for one year from the aster web site: <http://aster.unice.fr> ("Banque de données sismiques", "Sismicité", "catalogues").

Document 2

Using a spreadsheet software, construct a "cloud of points" graphic with longitudes for X-coordinates, and latitudes for Y-coordinates.



In superimposing this graphic with a world map, we show the regions where many strong earthquakes occur, and we illustrate the tectonic plates boundaries.





4. Piezo

Theme: Instrumentation

Objectives: Study of wave propagation for different materials

Keywords: Sensor, Wave Velocity, Density

Fields of work: Natural Sciences, Technology Sciences

Author: Hubert Ferry, Lycée Jean Moulin à Draguignan, France – Profdebio83@aol.com

From experimental measurements, we will demonstrate that the seismic waves velocity depends on the propagation medium properties.

1st step

Description of the experiment.

Two bars of different materials will be used: steel and concrete. On these bars, several piezo-electric cells will be deployed, to record seismic signal generated by an artificial shock (a hammer is used).

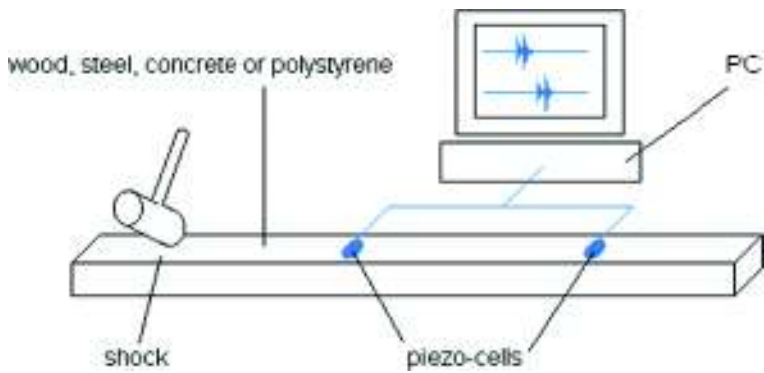
2nd step

The delay between the wave arrival times at the piezo-sensors allows us to calculate the wave velocity for the given material.

3rd step

It may be useful to confront the results with known information about seismic waves velocities in the materials we used.

More: It may be interesting to realise this experiment using other materials.



The bars used for this experiment have to be long enough to measure the time delay precisely. Thus, the shock has to be quite strong in order to see significant response signals. The two sensors are connected to a standard PC by its sound card.

Figure 1.

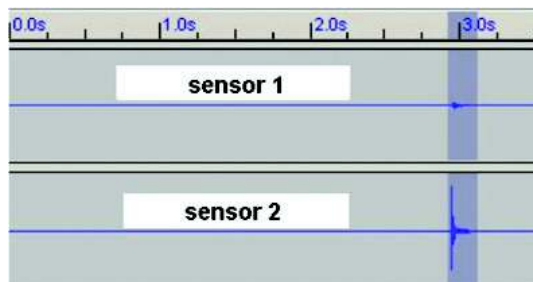


Figure 2.

Concrete: raw signal.

Concrete: zoomed raw signal.

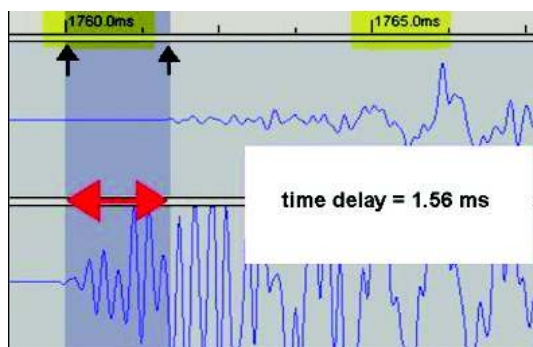
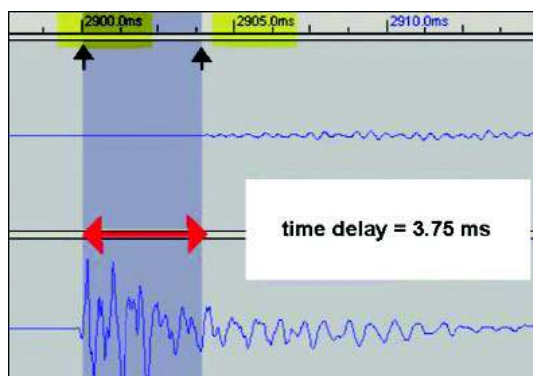


Figure 3. Steel: zoomed raw signal.

A classical sound analysis software is used to record the response signal. The seismic signal is recorded by the two sensors.

The software time scale allows us to measure the time delay between the two sensors precisely. For instance, a time delay of 3.75ms is measured for a distance of 7m between the two sensors (for concrete).

Then, it is possible to calculate the wave velocity in that material:

$$V(\text{concrete}) = 1.8\text{km/s}$$

A similar experiment may be realised using a steel sample. A time delay of 1.56ms is measured for a distance of 7m between the two sensors.

Then, it is possible to calculate the wave velocity in that material:

$$V(\text{steel}) = 4.3\text{km/s}$$

5. Rupture

Theme: Earth

Objectives: Record the waves generated by a break in different materials

Keywords: Hypocentre, Seismic Waves, Seismogram

Fields of work: Natural Sciences, Physics Sciences

Author: Hubert Ferry, Lycée Jean Moulin à Draguignan, France - Profdebio83@aol.com

A mechanical stress will be applied on different materials up their the rupture point. The waves generated by rupture are recorded by a piezo-electric cell fixed on the material.

1st step

Description of the experiment: Two layers of polystyrene are put on two wooden wedges, held by a cramp. A piezo-electric sensor is fixed on the superior layer and is connected to a standard PC by its sound card. A standard sound analysis software is used for signal recording and processing.

2nd step

Using the cramp, a vertical stress is applied on the polystyrene layers progressively. The layers are deformed: the acquisition is started. We increase the stress intensity up to the rupture limit. The acquisition is stopped when the layers break.

3rd step

A seismogram appears on the screen: the waves generated by the material rupture have been recorded by the sensor.

More: It may be interesting to realise the experiment with other materials, plaster or wood, for instance.

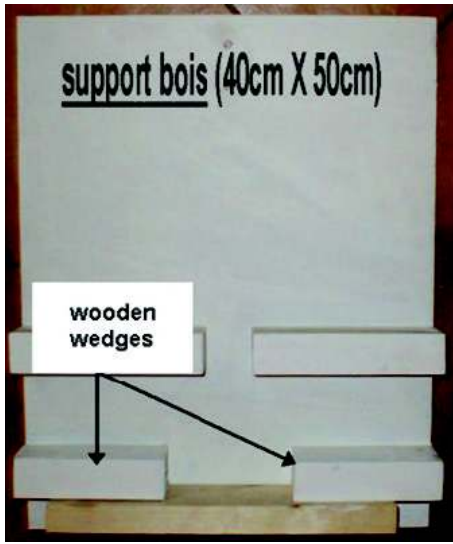


Figure 1. Polystyrene layers will be put on these wooden.

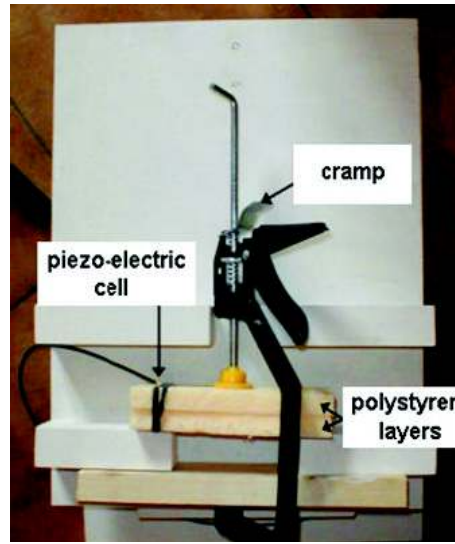


Figure 2. The piezo-electric sensor is connected to a standard PC by the "line in" soundcard input.

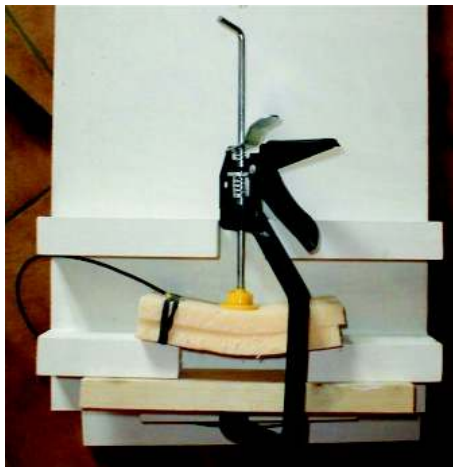


Figure 3. The layers are deformed because of the vertical stress: the acquisition starts.

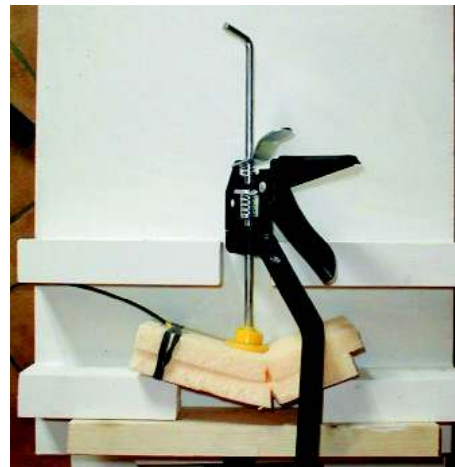


Figure 4. The rupture point is reached: the acquisition stops.

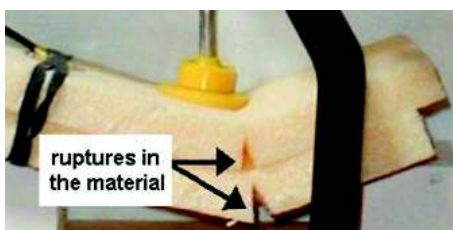


Figure 5. The waves generated by the material rupture are recorded using a standard sound analysis software.

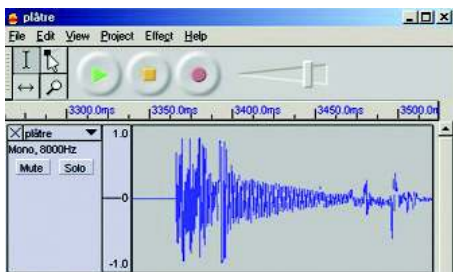
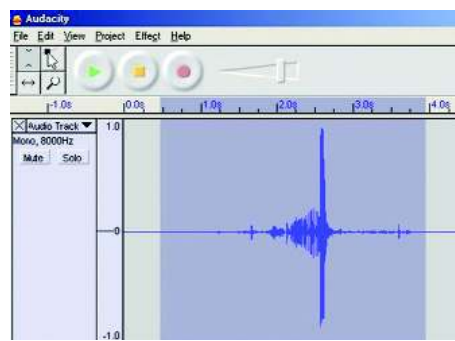


Figure 3. The layers are deformed because of the vertical stress: the acquisition starts.



Figure 4. The rupture point is reached: the acquisition stops.



6. Relationships between Amplitude-Magnitude, Magnitude-Intensity

Theme: Seismic Risk

Objectives: Find a relationship between the amplitude of soil motion recorded on the seismogram, the earthquakes magnitude and the affects associated with it

Keywords: Soil motion Amplitude, Macroseismic Intensity, Magnitude

Fields of work: Earth Science

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The magnitude of an earthquake is related to the quantity of energy which is transported by a seismic wave. The Macroseismic Intensity classifies the effects that an earthquake has on constructions and people. It's very important to clarify the difference between the sizes of the magnitude and the Macroseismic Intensity on the basis of the measurement made by the seimogram.

1st step

The maximum amplitude of ground motion associated with an earthquake changes with the variations of the magnitude, the frequency and the duration. A qualitative relationship between the amplitude and magnitude of the earthquake is obtained by measuring the maximum amplitude of ground motion. This is measured on the seismograms of events that have different magnitude, recorded at the same station.

2nd step

The Mercalli scale, measures the intensity of an earthquake on the basis of macroseismic effects. The students have to determine the maximum Macroseismic Intensity for a seismic event, from known magnitude, applying the empiric relationship between Magnitude-Intensity.

More: To describe the effects associated with the Macroseismic Intensity value in the epicentral area and to describe how they change as they get further away from epicentral area.

Document 1

Determination of maximum amplitude.

For instance take three events of Molise sequence, recorded by NAPI seismic station of EduSeis network.

Molise	Molise	Molise
date: 01/11/2002	date: 01/11/2002	date: 05/11/2002
time: 15:08:00.0 GMT	time: 17:21:00.0 GMT	time: 23:10:00.0 GMT
latitude: 41.69 °	latitude: 41.71 °	latitude: 41.67 °
longitude: 14.69 °	longitude: 14.81 °	longitude: 14.63 °
depth: 10 km	depth: 10 km	depth: 10 km
MI = 5.3	MI = 4.3	MI = 3.6

Since the station-epicenter distance for every three events, changes little, we can suppose that the three earthquakes have the same epicentral distance.

Chosen a component of the seismogram and measured the maximum amplitude of ground motion recorded, we can obtain a qualitative relationship between the amplitude and the magnitude.



Document 2

Determination of Macroseismic Intensity.

For the surface earthquakes of Central Appennine, the empiric relationship that ties the magnitude to the Intensity is:

$$M = 0,40 I + 1,69.$$

$$M = 5.3$$

I = IX General panic: considerable damages at the anti-seismic constructions; buildings collapse

$$M = 4.3$$

I = VII Panic: minimum damages to the buildings

$$M = 3.6$$

I = V Perceivable by every body: minimum structural damages

7. P and S Waves

Theme: Exploring the Earth

Objectives: This activity aims to introduce the concepts of seismic waves that are spread within the Earth. Using a 5-slinky model it's possible to generate a longitudinal and transversal pulse and determine the different propagation, velocity and polarization of different wave

Keywords: Longitudinal Waves, Transversal Waves, Pulse, Polarization and Seismic Source

Fields of work: Earth Sciences, Physic Sciences

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Mariella Simini, Teacher – Mariella.Simini@na.infn.it

Using a 5-slinky model it's possible to simulate the motion of the P and S body waves (longitudinal and transversal waves), that are spread together from the source.

1st step

To conduct this experiment, divide the students into five groups. At each group is given one of the five slinkys from the model. One person from every group, takes the free end of each slinky and stretches it out five metres. Another person acts as the operator and moves the wood-block (5-slinky model) in four different ways, generating P and S waves.

2nd step

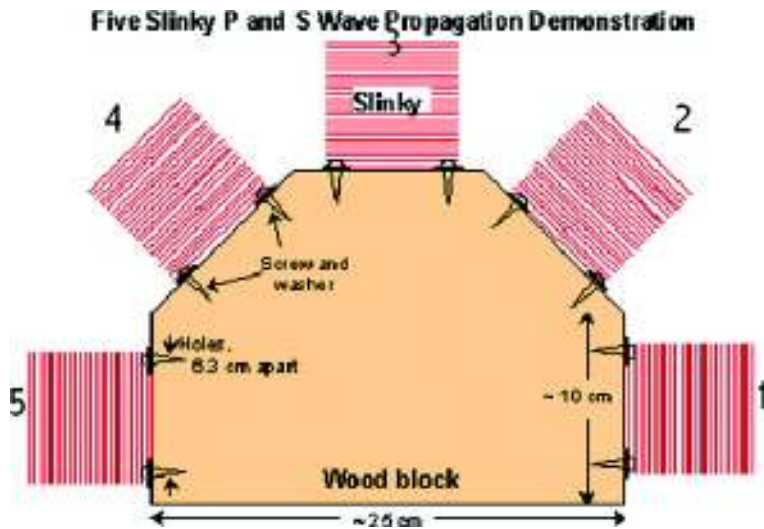
For each motion of the wood-block, every group records the types of waves that are spread along their own slinky. Using the chronometer each group measures the waves travel time along the slinky.

3rd step

Calculating the velocity of the body waves along the slinky.

Document 1

The 5-slinky model is a wood-block with 5 slinkys attached at different points, 45° away from each other.



The students determine the types of waves and measure the waves travel time along the slinky.

The data obtained is recorded in a table:

MOTION	POLARIZATION	TRAVEL TIME
UP-DOWN		
RIGHT-LEFT		
FORE AND AFT		
MOTION 45°		

Document 2

For each motion of the wood-block, every group the students determine the velocity of the body waves. Comments on the results obtained.

8. Signal Analysis

Theme: Data Analysis

Objectives: The amplitude, the Frequency, the Arrival Time and Duration of an earthquake, can be determined on a seismogram from the various waves types, propagated from the hypocenter

Keywords: Maximum Amplitude, Duration, Frequency, T_P Wave, T_S Wave

Fields of work: Earth Science, PhysicsEarth Science, Physics

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Different types of parameters can be calculated from the various waves types observable on the seismogram. Some examples of these parameters are: amplitude of ground motion, duration of the recording, frequency and principal phases. These parameters allow to characterise the typology of an earthquake. The shape, duration, maximum amplitude of ground motion and contents of frequency of a seismogram, change with epicentral distance and magnitude of an earthquake.

1st step

On a seismogram of a local earthquake, it's possible to define the time difference between first arrivals of P and S phase, maximum amplitude of ground motion, duration of recording and contents of frequency. The data obtained is recorded in a table.

2nd step

Comments on the measured data.

More: Try to determine the principal phases, the amplitude, the duration and the contents of frequency on a seismogram of a regional and of a teleseismic event. Remembering the classification of an event on the basis of the epicentral distance, it's possible to try to understand the changes of the measured quantities for different events.

Document 1

Determination of characteristic parameters by a seismogram: principal phases, amplitude, duration, contents of frequency. Working on a seismogram of a local earthquake.

Earthquake of 2001/03/05, Penisola Sorrentina: 01:09:00.0 GMT, magnitude 2.9 Md.

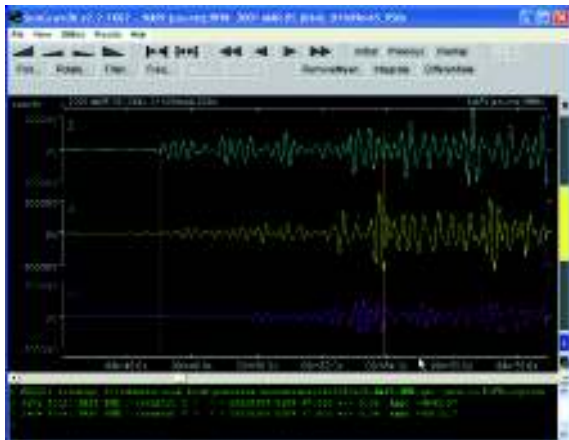
Considering the recording of NAPI station which is 32 km away from epicentral distance.



Individualisation of P and S phases and maximum amplitude.



Duration of recording.



During every 7 second intervals, the number of cycles is 13 and the frequency is equal to 1.86 Hz.

The data obtained is recorded in a table:

EARTHQUAKE	Ts-Tp	FREQUENCY	AMPLITUDE	LENGTH
Penisola Sorrentina	5.93 s	1.86 Hz	62613.6	88.05 s

Document 2

The students determine the P and S phases, the length, the maximum amplitude of soil motion and contents of frequency for the Egeo and Alaska earthquake to verify the changes of the parameters with the epicentral distance and magnitude. Comments on the results obtained.

Earthquake of 2001/07/26, Egean Sea:00:21:36.9 GMT, magnitude 6.0 mb (epicentral distance 879 km = 8°).

Earthquake of 2002/11/03, Alaska:22:12:41.0 GMT, magnitude 7.9 Mw (epicentral distance 7692 km = 69°).

9. Core

Theme: Earth

Objectives: Modeling the Shadow Zone on the Earth. Application of the Snell – Descartes theory

Keywords: Shadow Zone, Refraction, Seismic Wave

Fields of work: Physics Sciences, Experimental Sciences

Authors: Santos Maria Octávia, Escola Secundária Júlio Dantas, Lagos, Portugal – m.octavia@netvisao
Matias Luís Manuel, Departamento de Física, Faculdade de Ciências de Lisboa, Portugal – lmatias@fc.ul.pt

P and S waves travel through the Earth with velocities that depend on the density and elastic properties of the rocks. Just as light is reflected and refracted at boundaries where the refractive index changes, seismic waves bend when they cross a boundary where the rocks change their properties. Much of our knowledge of the Earth's deeper interior comes from studying the ways that seismic waves are reflected and refracted. For example the Earth's shadow zone, where direct P waves are not detected after an earthquake, is observed in the opposite side of the earthquake epicenter. This happens because the P waves are refracted at the core-mantle boundary (CMB). Analyzing this information the scientists are able to predict the core dimension and its physical state. The proposed experimental activity allows to model the P shadow zone and to understand why it has a "donut" shape.

1st step

Make the pupils aware of the existence of a shadow zone for the direct P waves, through scientific publications or iconographic documentation.

2nd step

Description of the experiment and the materials we will use: fish aquarium (radius = 8 cm) and bulb lamp (bulb radius = 4 cm).

The bulb lamp will be used, not as an electric component, but as a container, almost round and with very thin walls. So all the electric components inside were removed.

Acrylic support. Sugar solution (30 %; $n = 1,4$). Halogens lamp (20W, 12V). Photo plastic box.

Power supply: DC 1 alimentation 12V - D.



3rd step

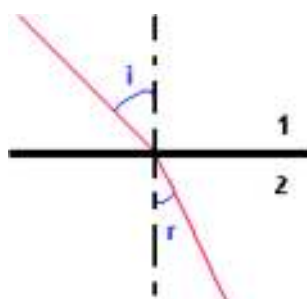
The aquarium plays the role of Earth, the bulb plays the role of the core. The seismic source is modeled by the halogen lamp. Two experiments will be realised:

- The aquarium's inside is filled with air, the bulb's inside is filled with sugar solution: a shadow zone appears on the aquarium surface.
- The aquarium's inside is filled with water, the bulb's inside is filled with sugar solution: no shadow zone is observed.

4th step

Discussion about P waves velocity in the mantle and in the core, and conclusions.

In this model, light rays generated by the halogen lamp play the role of seismic waves. Aquarium's inside plays the role of the mantel, the bulb's inside plays the role of the core. In filling the aquarium and the bulb with different solutions, we can simulate (or not) the shadow zone formation. It is possible to know the ray bending at a boundary between two different mediums in applying the Snell's laws:



$$\frac{V_1}{V_2} = \frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

The core / mantel proportions have to be respected:

$$\frac{R_{\text{aquarium}}}{R_{\text{bulblamp}}} = \frac{8}{4} = 2 \qquad \frac{R_{\text{Earth}}}{R_{\text{Core}}} = \frac{6371}{3480} = 1.8$$

Experiment 1

Hypothesis: P waves propagate faster in the core than in the mantel.

To verify that, the aquarium is filled with water, the bulb is filled with air.

$$n_{\text{air}} / n_{\text{water}} = 1/1.33, \quad V_{\text{air}} / V_{\text{water}} = 1.33$$

The waves propagation velocity is higher in the bulb than in the aquarium. That corresponds to our hypothesis. No shadow zone is observed.



Experiment 1

Hypothesis: P waves propagate faster in the mantel than in the core.

To verify that, the aquarium is filled with air, the bulb is filled with a sugar solution.

$$n_{\text{solu}} / n_{\text{air}} = 1.38, \quad V_{\text{air}} / V_{\text{solu}} = 1.38$$

The waves propagation velocity is higher in the aquarium than in the bulb. That corresponds to our hypothesis. A shadow zone appears on the aquarium's surface.



We have demonstrated that P wave velocity is higher in the mantel than in the core. In the classical documentation, we often find the following values:

$$V_p (\text{mantel}) = 11 \text{ km/s}$$

$$V_p (\text{core}) = 9 \text{ km/s}$$

$$V_p (\text{mantel}) / V_p (\text{core}) = 1.22$$

10. Rays

Theme: Earth

Objectives: Modeling the Seismic Rays path inside the Earth

Keywords: Seismic Ray, Refraction, Seismic Wave, Shadow Zone

Fields of work: Physic Sciences, Experimental Sciences

Authors: Santos Maria Octávia, Escola Secundária Júlio Dantas, Lagos, Portugal – m.octavia@netvisao

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P and S waves travel through the Earth with velocities that depend on the density and elastic properties of the rocks. Just as light is reflected and refracted at boundaries where the refractive index (or the speed of light) changes, seismic waves bend when they cross a boundary where the rocks change their properties. The proposed experiment allows to observe the rays path through different materials and to model seismic rays paths inside the Earth.

1st step

Preliminary discussion about the reality of a shadow zone on the Earth's surface for direct P waves, using scientific publications and iconographic documentation. It may be interesting to realize the experiment described in the activity called EduSeis - Core.

2nd step

We will work in two dimensions. The Earth's core is represented by a transparent disc in Plexiglas ($n=1.4$, radius=5 cm, thickness=15 mm). That disc is posed on a circle of paper with two different angular scales ($r=5$ cm and $r=10$ cm), to measure incidence and refraction angles. The Earth surface is represented by the circle with the larger radius. The seismic source is represented by a laser pointer.

3rd step

The angle of the emerging ray is measured while the incidence angle changes. Then, light rays path can be reconstructed.

4th step

Conclusions about the shadow zone for direct P waves.

It seems important to use Earth proportions:

Earth

$$R(\text{Earth}) / R(\text{Core}) = 6371 / 3480 = 1.8$$

$$V_p(\text{Earth}) / V_p(\text{Core}) = 11 / 9 = 1.22$$

Our model

$$R(\text{circle ext.}) / R(\text{plexi}) = 10 / 5 = 2$$

$$V(\text{air}) / V(\text{plexi}) = 1.4$$



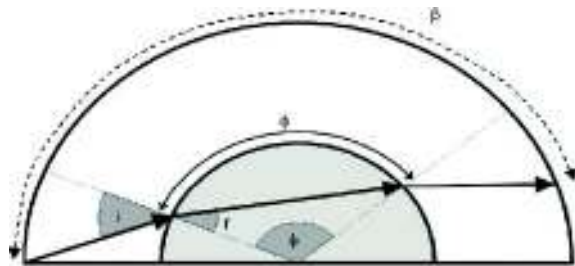
The incident angular distance of a laser beam at the acrylic ("core") and the emergent angular distance on the exterior paper ("Earth's surface") could be measured. Changing the incident angular distance ($0^\circ - 40^\circ$) we can reconstruct the distinct different ray paths.

i - Incident angular distance
 β - Emergent angular distance

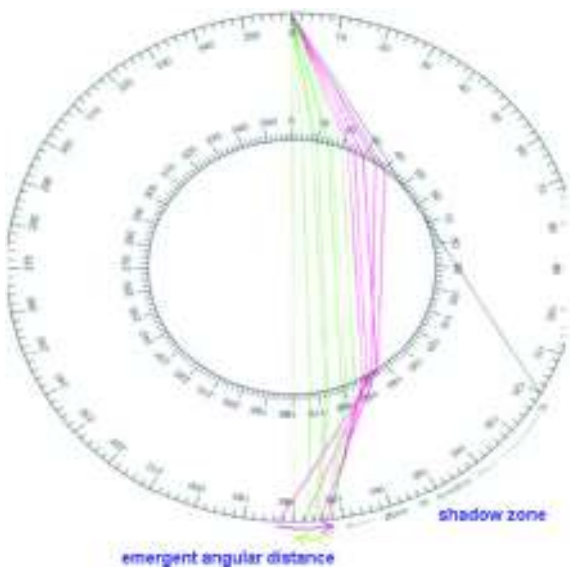
The value for the refractive index (n) of acrylic is given by:

$$n = \sin(i) / \sin(r)$$

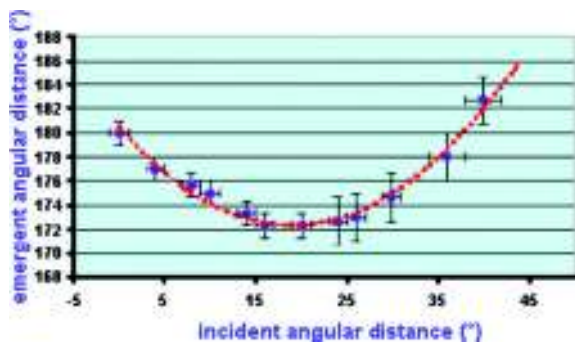
where $\sin(r) = \sin[(\beta - i) / 2]$
 (i and ϕ are read on the paper circle scale directly).



In plotting the rays paths for different incidences, the following figure is obtained:



- Several observations can be done:
- The formation of a shadow zone on the external circle (from 120° to 172°).
 - The inversion of the emergence for incidences comprised between 20° and 45° (see below).





11. Shake Detection

Theme: Sensors

Objectives: Study of technological solutions for seismic shakes detection

Keywords: Sensor, Seismic Shake

Fields of work: Technology Sciences

Author: Franck Pascucci, Collège J.-B. Rusca, Saint-Dalmas-de-Tende, France – fpascucci@aol.com

Pupils discuss about the conception of a model that allows earthquakes detection. Different simple devices are shown and they are invited to imagine other systems.

1st step

Through historical texts and iconographic documentation, it may be interesting to show how much the earthquakes detection has been studied in the human history.

2nd step

Preliminary discussion: How can we build an object that would detect an earthquake? Pupils present their projects with several schemas.

3rd step

One of the presented projects may be selected and its conception may start. If not, existing models may be shown to the pupils who have to understand how they work.



Figure 1. One of the historical earth quake detector (China, 2nd Century).

Height dragons hold a bronze ball in their mouth. An internal mechanism, started by the ground motion, opens one of the dragon's mouth and one of the balls falls down. The direction where the waves come can be determined by that system.

Two quakes detectors conceived by pupils:

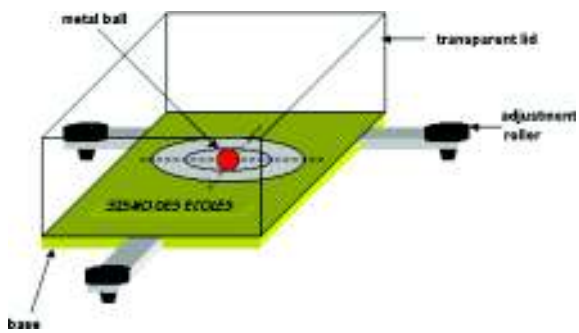


Figure 1. Seismic ball.

The three rollers have to be adjusted so that the basic support must be perfectly horizontal. The metal ball is posed at the circles centre. The transparent lid prevents the system from possible draughts. When a quake occurs, the ball leaves its initial position and comes to one of the engraved circles.

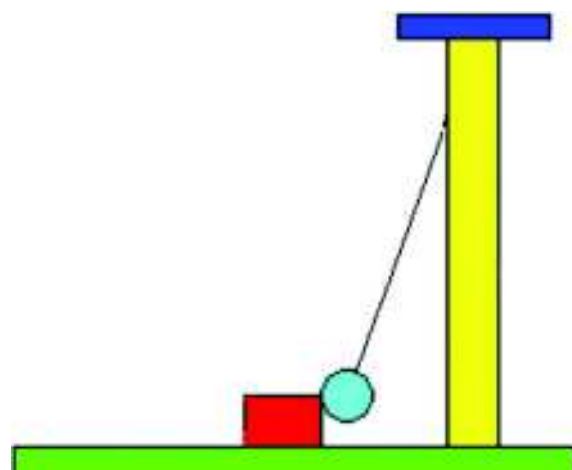
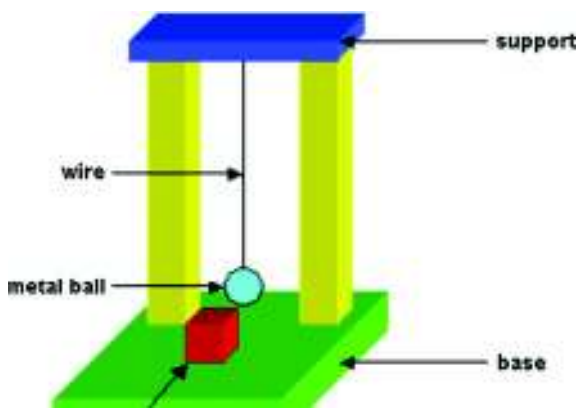


Figure 3. Seismic pendulum.

This vertical pendulum is composed with a metal ball suspended to a solid support. A magnet is fixed on the basic support just at the attraction limit. When a shake occurs, the pendulum oscillates and the ball is attracted by the magnet.



12. Seismometer

Theme: Sensor

Objectives: Objectives: Understand how an horizontal seismometer works and measure the ground motion with this sensor

Keywords: Seismometer

Fields of work: Physic Sciences, Technology Sciences

Author: Franck Pascucci, Collège J.-B. Rusca, Saint-Dalmas-de-Tende, France – fpascucci@aol.com

Pupils will manipulate a long-period horizontal seismometer to understand how it can record ground motions. They will realise some experiments using that sensor.

1st step

After a first discussion, instructions are given to allow of the assembly seismometer (spare parts of the model are provided).

2nd step

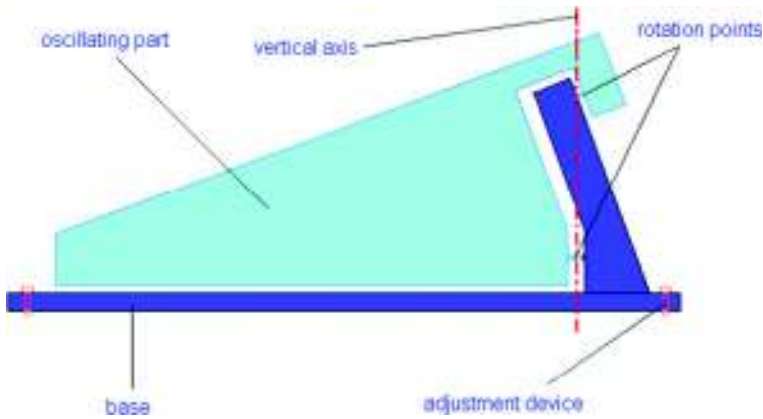
After basic manipulations of the sensor, pupils have to imagine how to proceed to record the vibrations: smoked paper roll, electrical device, ...

3rd step

Tests of the system through several experiments: sensor response for shocks of different intensity and different frequencies, one-day or one-week recordings, ...

More: It may be interesting to use the oscillating table to improve the measurements.

Figure 1. Horizontal seismometer assembly.



The sensor's principle is quite simple: The base (in dark blue), is posed on the ground horizontally, using the adjustment rollers. The oscillating part is put on that base by 2 nails. There's a very small offset between the line formed by these 2 rotation points and the vertical axis, to allow the oscillation.

When the sensor is disturbed by a shake, the oscillating part behaves like a pendulum. It oscillates around its inclined axis. It is important to note that the smaller the inclination angle is, the more the oscillation period is large. That's why this kind of sensor is called "long period" seismometer.

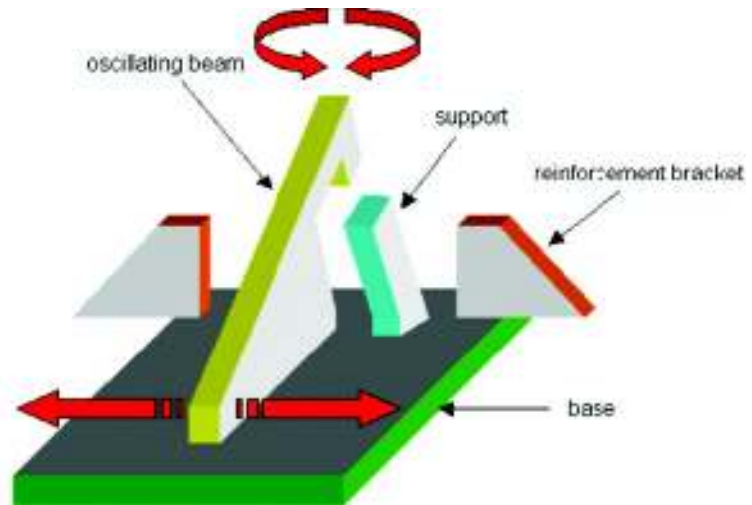
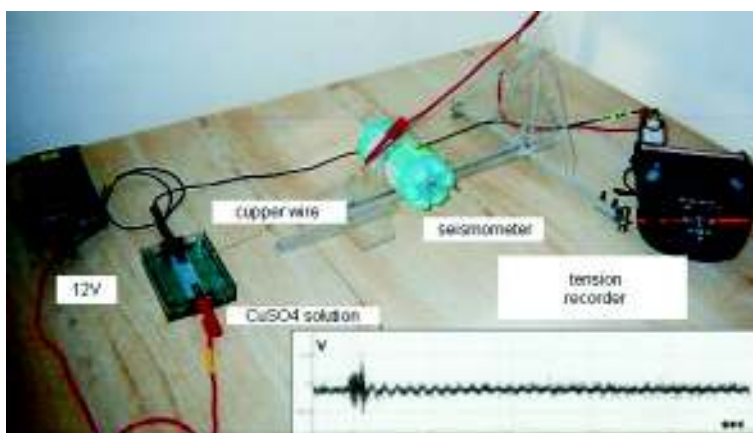


Figure 2. Signal recording.



The copper wire fixed to the oscillating beam is moved by an artificial shake. That copper wire is in contact with a rheostatic solution, supplied with a DC 12V current. This displacement generates electric tension variations that can be recorded on an oscilloscope or using a A/N digitizer.

13. Seismic Cycle

Theme: Exploring the Earth

Objectives: Using a model that may be constructed by the pupils, the relative displacement of two blocks under a tectonic stress will be modelled

Keywords: Seismic Cycle, Tectonic Stress, Modelling

Fields of work: Physic Sciences, Earth Sciences

Author: Chantal Otto, Centre International de Valbonne, France

We will use a carpet moved by an electric engine with a constant velocity, to model the behaviour of two blocks under a tectonic stress. One of these blocks is modelled by the moving carpet, the other by a wooden cube posed on the carpet. The upper block is linked to a dynamometer by a spring, the accumulated energy can thus be measured.



1st step

Discussion about how the energy is accumulated when a tectonic plate is subjected to a tectonic stress, and about how the fault breaks when this energy becomes to high.

2nd step

Description of the experiment.

3rd step

Pupils are invited to perform several measurements, and to use various input parameters: engine's velocity, materials roughness, mass of the upper block.

4th step

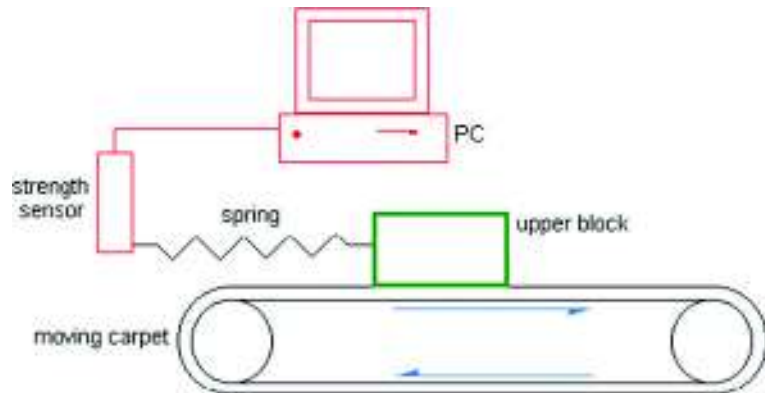
Discussion about the obtained results.

Document 1

Schematic description of the model used for our experiment.

A specific force sensor, connectable on a standard PC by its interface is used.

The experiment may be realised, also, with a standard dynamometer. In that case, the force intensity has to be read on the dynamometer graduation directly.

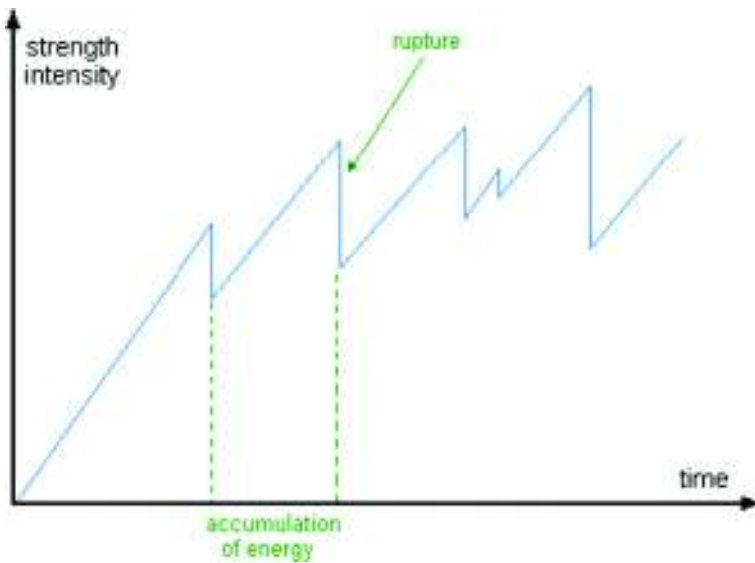


Document 2

Results

When the engine starts, the upper block is moved and keep in contact with the carpet: the spring lengthens.

After seconds, the energy accumulated by the spring is high enough to generate the dissociation of the two blocks, the upper block moves on the carpet surface, abruptly. The energy accumulated in the spring is liberated, totally or partially, and the upper block is again moved by the carpet up to the next rupture. That cyclic process can be observed on the following graphic.





14. Resonance

Theme: Seismic Risk

Objectives: Understand the frequency effects in the seismological hazard estimation

Keywords: Seismic Wave, Frequency, Seismic Hazard, Resonance

Fields of work: Physic Sciences, Technology Sciences

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When some strong earthquakes occur, we sometimes observe that the damaged buildings have a comparable high. We propose to discuss about the relationship between the buildings high and the damages. It's necessary to introduce the frequency and resonance notions.

1st step

Study of historical events where such observations can be done: the 1985 Mexico earthquake, for instance.

2nd step

Pupils are invited to construct a model showing how buildings of different high behave when they are shaken.

3rd step

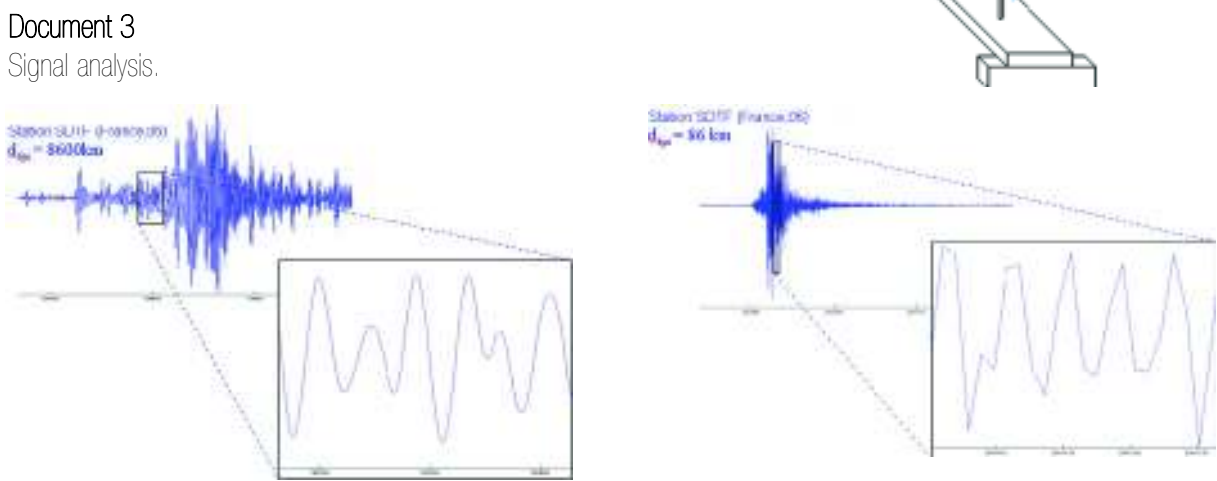
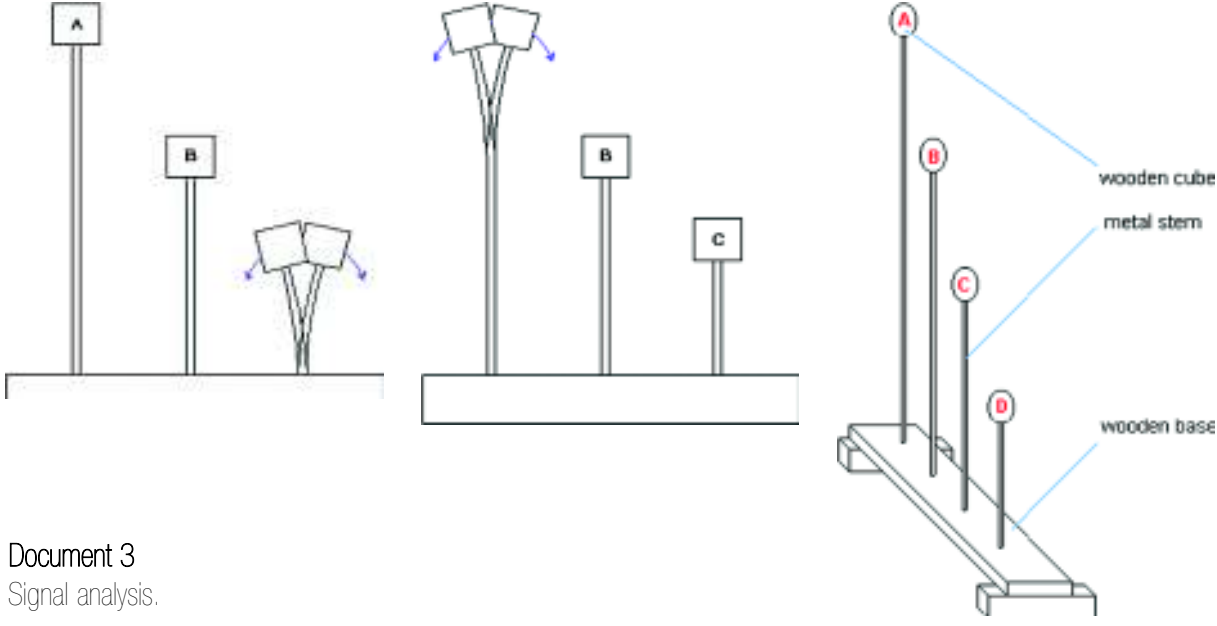
We will see that the main frequency of the signal recorded at a given station depends on the epicentral distance.

More: It may be interesting and important to note and to show that the high of the building is not the only parameter to be involved in its behaviour when an earthquake occurs.



Document 1
 Study of specific documentation.
 When the 1985 earthquake affected Mexico City, located 400 km far away from the epicentre, most of the damages were observed for high buildings. Their own period was estimated to about 2 seconds.

Document 2
 Modelling the building behaviour.
 The model is composed of a wooden base, that represents the ground. Four buildings are represented by metal stems of various high. A wooden cube, at the top of each stem is used to amplify the stem oscillations. The stem diameter is 4 mm, the high is comprised between 300 and 900 mm.



In analysing the signal recorded for various epicentral distances, we observe that the wave frequency is higher for a local earthquake than for a far event. Thus, we show that the lowest buildings will be more affected by very close shake, while higher buildings should be more damaged by very far earthquakes, in theory.



15. Station

Theme: Sensors

Objectives: Implementation of a numerical seismic station in a school

Keywords: Seismic Station, Seismometer, Seismic Data

Fields of work: Seismology, Physic Sciences

Author: Thomas Picq, Centre International de Valbonne, France – tpicq@mail.civfrance.com

When a seismological station is installed in a school, it seems useful for the pupils and the involved teaching staff to be aware of the function of the various elements: sensor, gps, digitizer, ... It is also necessary to show the technological and scientific requirements to respect in such an installation.

1st step

The first step consists in showing up to what point it is interesting to deploy a seismological stations network to record and analyse local, regional and world events.

2nd step

It seems necessary to present the station components and to explain what role is played by each of them. Discussion may start to decide where the GPS, the sensor and the station have to be installed inside the school.

3rd step

Pupils are invited to learn how the recorded data can be retrieved online, and how it is possible to confront the data recorded by their station with other recordings.

Document 1

Preliminary discussion.

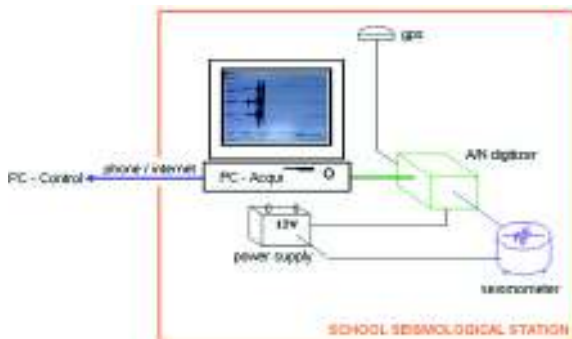
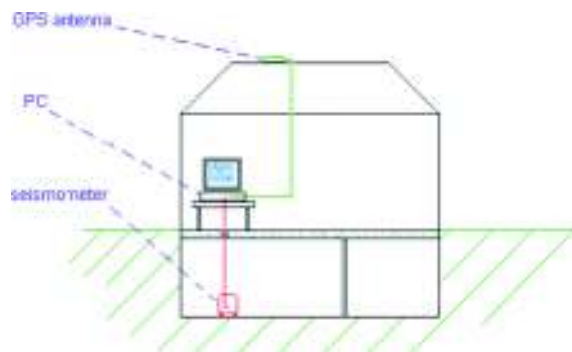
Several weeks before the installation of the seismological station inside the school, it is important to start a discussion about the pupils and the involved teachers: how does it work? What conditions have to be respected in this installation? What direct educative applications could be imagined from the recorded data?

Document 2

Installation of the seismological station.

The seismological station is composed of the following components:

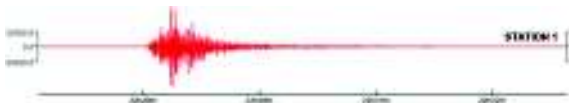
- 1 seismometer: it records the ground motion continuously. It has to be put on the rock basement.
- 1 GPS antenna: it gets GMT time from the gps satellites. It is installed on the roof.
- 1 A/N digitizer: it converts analogical signal from the sensor into numerical data.
- 1 standard PC: it is the acquisition manager. It is also in communication with the central network PC for data extraction.



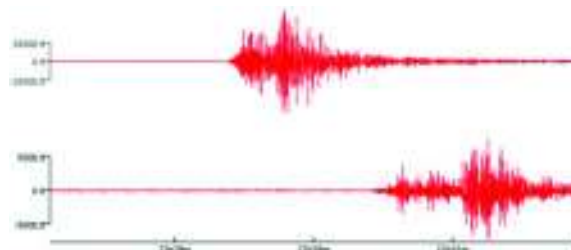
The seismic signal is extracted from the station to the central PC through phone connections or internet. Then, the recorded data is published on the web, automatically. Pupils are thus able to retrieve the data recorded by their station, in addition to signal from other stations. That data is the base of many educative applications linked to seismology.

Document 2

Confrontation of several signals.



Signal from the station.



Signals from other stations.



Scientific manifestation.





Working group on landslide illustration.

