

# DIAMAGNETIC SUSPENSION SEISMOMETER

Proposed by

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## ***1.0 The Project***

### *1.1 Introduction*

Dr. Knecht has given the EPICS 151 teams the challenge of completing the design project suggested by John Lahr of the US Geologic Survey. We received a letter from John Lahr and Thomas Boyd of the Department of Geophysics, requesting that our team design and build an inexpensive, long-period sensor for seismic waves. First we would like to thank the clients for taking the time to meet with us. After meeting with them, our perception of our task became much clearer. Together with the Globe program, they intend the seismometer for use by students and instructors ranging from kindergarten through college, but primarily focused on high school use. Unfortunately, most commercially produced seismometers cost in excess of \$500, well beyond a normal school budget. Therefore the challenge is to produce a seismometer with the capabilities of any expensive equipment, but for a fraction of the cost, precisely no more than \$150. [1]

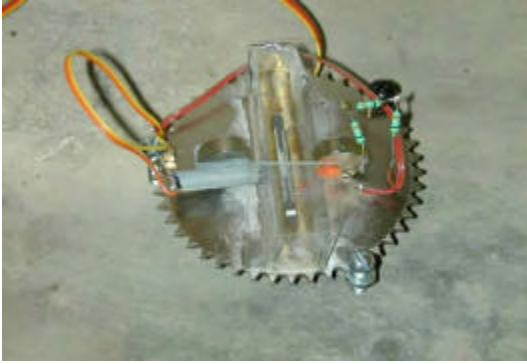
### *1.2 Constraints*

We see the \$150 limit as the main constraint of the project, but there are numerous other demands we must meet. The seismometer must be sensitive enough to detect an earthquake anywhere on the earth of a magnitude six or greater on the Richter scale. That requires a one to twenty second period, an amplitude ranging from  $5.61E+01\mu\text{m}$  to  $7.93E+01\mu\text{m}$ , and a velocity ranging from  $1.76E+01\mu\text{m}$  to  $4.98E+00\mu\text{m}$ . With these specifications the instrument can take readings at any distance on the surface of the earth. Our second main constraint is the ability to record data. The seismometer must transfer data to any PC using either the serial port or the game port. In doing so, a series of other devices, including an amplifier, AD converter, and filter, must be implemented into the design. Another limitation on the seismometer is safety. Since it will be placed in schools from kindergarten up it is rather important that the seismometer will not create an unsafe environment for the children, enabling children to observe the seismometer safely. The last major requirement for the design of the seismometer is fabrication. Since it is designed for school use, a teacher or student with little or no mechanical ability should be able to build one with the basic components. [1] Considering these numerous restraints, our team aims to build the most cost-efficient and best working device within the mentioned constraints.

### *1.3 Design*

We have decided to design a seismometer after the diamagnetic suspension seismometer shown in figure 2.1, to measure horizontal movement of the earth. [2] The Lehman

models were options but are more expensive to replicate than the diamagnetic suspension seismometer. One of our other options the pendulum is shown in appendix figure



**FIGURE 1.1:** Previous diamagnetic suspension seismometer [2].

A-1. Therefore, we plan to design a sensor using a rod of graphite and a few powerful magnets. Research shows that this plan is within the specified price range and will produce excellent data. A horizontal model using a sensor made of graphite and magnets coupled with an LED and photo resistor is sensitive enough to sense a magnitude six from any distance. The seismometer will be connected to the PC using the serial port. Research found that connecting through the game port would cause additional problems and increase our cost. [3] After speaking with

the clients we found that the ten-bit AD is compatible with the AmaSeis software. Therefore we will also implement the ten-bit AD into our design as well. [4] There are few if any safety hazards with the diamagnetic seismometer. The magnets are powerful but will be safely secured to the iron base. To insure no damage occurs to the seismometer itself due to its sensitivity, a small fish tank will set upside down on top of the seismometer providing observation for the students, as well as safety.

### *1.4 Project Divisions*

In order to efficiently complete the project we have divided our project into the following subsystems:

- Materials
- Graphite and Magnets
- LED and Photo Resistor
- Calibration
- Overall Design
- Research and Technology

Matt is in charge of materials; he will order the correct materials at an inexpensive price, as well as, keep track of our budget. Jason designed and researched the magnets and levitating graphite. Brodie researched and designed the electronic components including the LED and photo resistor. When the seismometer is completed, Brooke will be in charge of calibrating the system, as well as partnering up with Heather to work on the overall design to insure everything is complete and functional. Heather will also be working on research and technological information, which will be used to improve or find information on the design and provide capabilities and compatibilities of the electronics.

## **2.0 Subsystems**

### *2.1 Materials and Cost*

The magnets are the center of this project. Matt found the cheapest NIB magnets on the internet at a local company called Force Field Magnets. He spoke with Force Field and Meredith Lamb, a local expert on graphite levitation, and they helped our team with ordering the magnets and explained that the N45 gold-plated magnets would work the best. Each magnet is 1" long and 1/4" in diameter. Eight magnets cost us \$24.00 plus shipping. [5]

For the graphite we explored several sources. We went to Dr. Pewter in the metallurgy department at the Colorado School of Mines. He provided our team with some graphite rods 1/8" in diameter that work and gave us the information of the company they order their material from. We then talked to Dr. Lahr at the USGS and he informed us that his web page notes which pencil lead companies have a lead that will levitate. [6] Finally Mr. Lamb informed us that Farber Castell pencil lead has levitated the best for him, this can be found at Meininger's Art Supply and other art supply stores around the world. Farber Castell 1.4 mm type B lead comes in tubes of six sticks for \$1.45. [7] Though this is the cheapest and most convenient lead to get it is too small to support the weight of the aluminum sail, therefore we will use the 1/8" diameter graphite provided by the metallurgy department.

We have decided to implement the ten-bit converter from Dataq Company for \$25.00 and the free software from AmaSeis software. [1] One item that was later included by the group after talking with Mr. Lamb is the need for an iron base under the magnets to increase the magnetic field and increase levitation height. [8] Machinist Mark Hankie told us that machine shops normally have extra iron would probably be willing to give it away. [9]

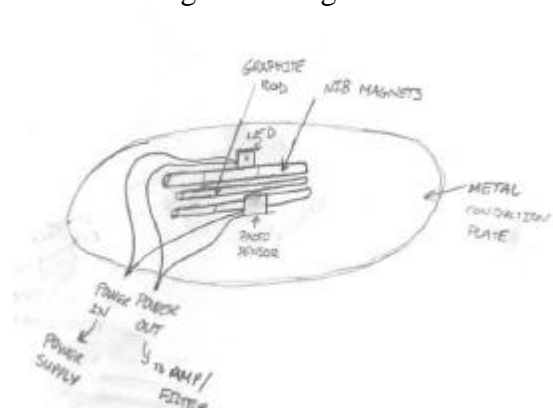
Electronic components have been the easiest to find, Radio Shack stocks LEDs and photo resistors. These are available online or at the stores for a total of \$3.00, this includes four extra sensors. [10] Also we decided to buy a fish tank from Pets Mart, costing about \$5.00 plus tax. Some components of the seismometer are such common household items that their cost is insignificant. Simple household aluminum foil and cardboard boxes, which can be picked up from a local grocery or liquor store, are a couple examples. The price list may be found in appendix table A-1.

### *2.2 Graphite and Magnets*

The main focus of all research done on this subsystem has been on floating the graphite with the magnets. Most of the information available is based on experiments with diamagnetic materials. [5] Unfortunately, the arrangement of the graphite and Neodymium Iron Boron (NIB) magnets is beyond our abilities and price ranges. [6]

Many times the experiment hung a large NIB magnet above two sheets of graphite to float a very small magnet between the sheets. [11] Two possible solutions to levitating the graphite were first presented. They were to lay the magnets end-to-end in two rows, or stand the magnets on end, each alternating the poles in two columns. Each solution has positive and negative effects to the overall design. By laying the magnets end-to-end we can have a greater length than by standing them each on end making calibration more precise. The unfortunate side to this arrangement is that the poles of the magnets will not be as easily distinguishable. Standing the magnets on end will make it easy to distinguish the poles and orientation, but we will have to sacrifice overall length, which will be crucial in calibration. The N45 magnets purchased from Force Field will work perfectly because they are polarized across the diameter and will provide enough length for precise calibration.

Research has provided information that is critical in designing the seismometer and magnetic subsystem. The original design shown in figure 2.1, used two columns of NIB magnets that would produce a magnetic field to levitate a graphite rod. [2] This is possible simply because graphite is a diamagnetic material. A diamagnetic material is one not as magnetically permeable as air or a vacuum and is actually repelled by magnetic fields. Because of this repulsion, graphite can be levitated if a strong enough magnetic field is produced around it. Experiments in Europe have been able to levitate other diamagnetic materials including a live frog.



**FIGURE 2.1:** Lead Head's original design plan for the diamagnetic suspension seismometer.

The basic concept of floating graphite is to have the rod suspended between the attractions of two unlike poles and have the lift and weight forces in equilibrium. [11] To find the poles of each magnet we must float a magnet in water as a compass to determine north and then match it with each south-pole of the other magnets. Another method is to simply test which ends attract and repel and label accordingly. [5] After doing so we can lay them alternating the poles as according to previous experiments. [6] The magnets purchased for this arrangement are cylinders approximately a  $\frac{1}{4}$ " in diameter and a one inch in length and are polarized across the diameter. Currently our team has eight magnets to position within the seismometer for this configuration. The second arrangement is standing magnets with the poles on the ends at angles to each other. The

particular magnets Force Field produces of this type are a ¼” in diameter and ½” in length. Either option will require an iron mounting to amplify the magnetic field and a rod of graphite filed into a half cylinder. The half cylinder is required for rotational stability otherwise the rod will want to roll within the magnetic field. The length of the rod will vary depending on the period we desire and is therefore subject to the calibration subsystem.

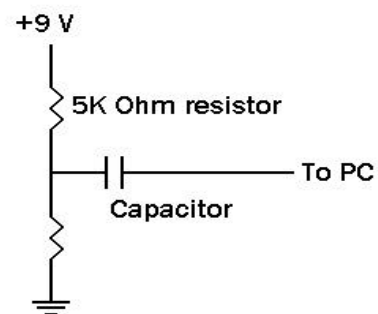
Assembly of the subsystem will involve securing the assembly to the iron base. No glue will be necessary with the magnets since they will have a strong enough attraction to the base that they will not move. The magnets are positioned in two lengthwise columns with about one-eighth of an inch gap between the rows. Simply leaving a thin piece of cardboard for spacing is ample. If the other magnets are used they must be positioned at relative angles to each other. They will be secured to two angled pieces of iron creating a ninety-degree angle. They must also be positioned such that the opposite poles alternate across the gap and down the row. This creates a damping effect. After filing the graphite into a half cylinder a piece of aluminum foil will be wrapped around it to provide crucial damping. Once constructed the levitating graphite should theoretically remain stable when the earthquake passes while the remaining systems move allowing the photo resistor to receive the LED.

### 2.3 LED and Photo Resistor

To detect an earthquake one needs something to sense the movement of the ground in relation to the levitating graphite. This can easily be done by using a sail on the graphite to block the light emitted by the LED on one side of the row of magnets, and a photo resistor on the other side of the magnets. When the photo resistor detects the light of the LED it will emit a resistance to a coupled voltage based on the amount of light received. This voltage can be measured and in turn we can interpret the size of the earthquake. [2]

Up to now various methods of sensing this movement of graphite have been researched. The sensors we are using are the LED and photo resistor method, measuring the voltage emitted by the electromagnetic field between the graphite and magnets, or using a force sensor to obtain the pressure the graphite emits when it moves. [2, 3]

The best solution to the problem of sensing the motion of graphite would be the LED and photo resistor method. Table A-2 in the appendix shows our decision process. There is no inexpensive and practical way to measure the electromagnetic field between the graphite and magnets. In fact, the technology is so primitive that there was not enough evidence to even explore that option. As for the force sensor, it could not pick up the proper frequencies required to detect a magnitude six or greater earthquake. It is therefore concluded that the most effective and inexpensive design would be the LED



**Figure 3.1:** Electronic circuit connected to CdS photo resistor.

and photo resistor method. It is very inexpensive and it has been previously proven to work for this design. [2, 12]

Based on the specifications of the photo resistor and LED, they should meet the requirements that the client has requested. The challenge is to calibrate the entire sensor to detect the proper periods and frequencies of an earthquake that is magnitude six or greater. This calibration is actually done through the damping of the graphite and the adjustment of the length of the graphite to detect the proper period. The photo resistor and LED are merely devices that detect movement of the graphite; they do not determine the period or wavelength. [2, 4]

Both the LED and photo resistor have been proven as environmentally and physically safe. The voltage we are using to run the sensor is not great enough to cause any bodily or environmental harm. [10]

The LED and photo resistor are actually two separate components of the entire final design. The LED and photo resistor are purchased pre-assembled so only their placement and orientation must be constructed. The LED is a common small diode and the photo resistor is a cadmium sulfide composite resistor. Based on previous models of a diamagnetic seismometer, we will place the LED on one side of the rows of magnets and place the photo resistor on the other side of the rows of magnets. The LED will be mounted to shine directly on the photo resistor. Three volts from batteries supply the power to the LED. The shutter on the graphite will partially block this light, allowing us to sense the movement of the graphite. This can be seen in the preliminary design drawing. (See Figure 2.1) The photo resistor is coupled to a small circuit within the design. This circuit is composed of a nine volt battery supplying power through two 5K Ohm resistors, the CdS photo resistor, and capacitor. (See Figure 3.1) When the shutter allows light to contact the CdS surface a significant change in voltage from the power source is detected and interpreted by the computer as earthquake waves. Experiments show that it may be necessary for the seismometer to be placed under darkness since the photo resistor is extremely sensitive to all types of light and it is preferable that the only light it detects is emitted from the LED for correct data.

#### *2.4 Calibration and Overall Design*

The best way to calibrate a diamagnetic seismometer is to damp the unit using either copper wire or aluminum foil and shorten the graphite rod on a trial and error basis to obtain the longest period possible. [2] Mr. Lamb confirmed that using a trial and error and filing the graphite until it is the correct length and centered will work, and also shared much of his experience with damping the periods. He also informed us that he has never obtained a period of twenty seconds, but that a man in California had.

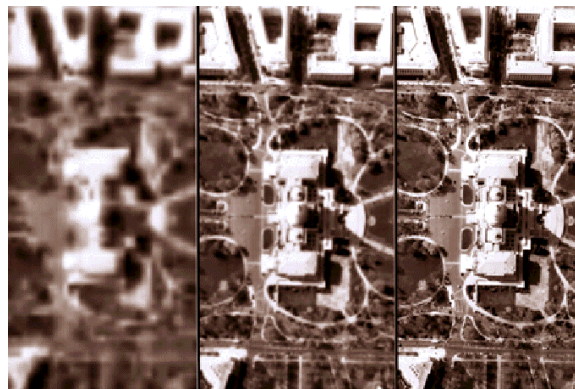
Assembly of the overall design requires that every team member's subsystem is placed properly. The design consists of a circular iron plate with three leveling screws in around the circumference to level the seismometer. The magnets are laid horizontally in two rows, spaced so as not to touch each other, centered on the iron base. Graphite wrapped

in a small aluminum foil shutter levitates centered above the magnetic rows. The small “shutter” made from aluminum foil that is positioned between the photo resistor, and the LED, each of which is secured to the base. Over the seismometer a small fish tank is placed to protect it from destructive elements. The fish tank will provide observation as well as protection from bumps or breezes that could disturb the graphite and skew the data. When the seismometer senses earthquake waves the graphite will move horizontally across the magnetic field indicating the amplitude of waves felt.

## 2.5 Research and Technology

Research provided different options in models and within our own model. We were able to collect data in such a way that it did not slow down the production of our seismometer even if there were some aspects that need to be researched later during the construction process. This subsystem also allowed our team to insure the web site and other sources of information were all kept together for future references. The second component to this subsystem is technological information. Technological information was created to insure the compatibility of the electronic parts, and compatibility of software, as well as other methods of connecting to the PC.

Through research we have found that previous attempts of our design worked to a degree. However, we have found it difficult to float the piece of graphite and there have been difficulties in calibration for the diamagnetic seismometer. Research found another type of magnet that levitates the graphite with no complications. It was also discovered the importance of the iron plate opposed to the original wooden structure.



**FIGURE 4.1:** Hypothetical resolution of the twelve bit (far right) vs. the ten-bit (far left) [13].

We decided incorporate the ten-bit AD converter as opposed to the twelve bit AD converter. The only noticeable difference between the two besides price is resolution. The twelve bit’s resolution is much clearer than the ten-bit’s but still provides the same information, this is illustrated in figure 4.1. The twelve and ten bit AD can be found in appendix figure A-2. Through these subsystems we also found that it would benefit us to connect through the serial port of the PC as opposed to the game port because we would have to generate our own software compatible with the game port. Both the serial and game port may be seen in figure A-3 in the appendix. In addition connecting through the

game port or using the twelve bit AD converter is too expensive, doubling the cost of the seismometer. Connections for the seismometer may be found in figure A-4 in the appendix

### ***3.0 Conclusions***

#### *3.1 Safety and Maintenance*

Since the seismometer will be placed in schools from kindergarten up it is extremely important that a safe environment is sustained and little or no maintenance is necessary. Our design presents few if any safety hazards. The magnets are powerful but will be safely secured to the iron plate. The magnets' attraction are only substantial enough to attract very close items, not enough to attract to anything that could be close to the seismometer such as chairs, metal rulers, or other magnet items. A fish tank will also be placed on top of the seismometer to insure that the children may see the seismometer work but not harm the seismometer itself. Maintenance is merely checking occasionally that the graphite is still levitating centered between the rows of magnets and changing the batteries when they run out of power.

#### *3.2 Final Comments*

Our design fits the requirements placed on the project given to us by John Lahr and Thomas Boyd. Our seismometer design is sensitive, produces a twenty second period, connects to the PC using the serial port, produces magnificent data, and most importantly costs well below under \$150.00. Our design can be safely implemented into school systems, easily connecting with the amplifier, filter and ten-bit AD converter that were required as well. Compared to other designs, the diamagnetic seismometer is safer, smaller, and cheaper. Our design does not incorporate any sharp edges or any glass that could become a safety issue, much unlike seismometers of the typical Lehman model. Nor does our seismometer include a container of viscous fluid that Lehman model may, which could prove to be a potential mess.

Clearly our design is the ideal solution for this project!

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