Name ____________________________

Challenge Worksheet

Geophysics of Earthquakes

Lab 3: Handheld Seismometers

Background: Most seismometers detect ground motion using a mass that is suspended in some fashion by a spring. When the ground moves the seismometer's frame also moves. The mass tends to remain relatively still, however, because of inertia. The relative motion of the mass with respect to the frame (and thus the ground) is then converted to an electrical signal (voltage variations with time) using a capacitor plate, a galvanometer, or a magnet and coil assembly. Seismometers are usually sensitive to one component (direction) of ground motion (vertical or horizontal) and thus three components are used to completely characterize the seismic signals.

The magnet and coil sensor (the type we will be building) operates by measuring the change of the magnetic field by the amount of voltage produced in the surrounding coil. The sensor characteristics (primarily its sensitivity) are controlled by the strength of the magnet, the number of turns of wire in the coil and the distance of the magnet from the coil. Once the sensor is constructed, it is easy to demonstrate that the electrical output of the sensor is proportional to the velocity of the mass through the coil.

Your Mission:

(1) Construct your own hand-held seismometer.
(2) Test the properties of the seismometer using (1) different magnets (2) different springs (3) rubber bands.
(3) Explore the applications of a seismometer.

Your Supplies:

- Wood block
- 1 -- 6in 1/2" PVC pipe
- 2 -- 1ft 1/2" PVC pipe
- 2 -- 1/2" PVC 'Elbow' joints
- Factory spring (gray)
- Red magnet wire (~5 feet)
- Gold magnet wire (~3 feet)
- 2 -- Round Magnets
- 3 -- rubber bands
- 1 plastic container
- 1 -- 5" x 1/4" Eyebolt
- 1 – 3" Eyebolt
- 2 -- 3/8" washers
- 2 -- 1/4" washers
- 6 -- 1/2" washers
- 4 -- 1/4" nuts
- piece of sandpaper
- double sided tape
- regular tape
- 1 pencil or pen

Your Blueprints:

You will be building the instrument illustrated in Figure 1 (page 4). Refer to this figure for a visual picture of supply pieces and names.

Step 1: Assembling the structure

1. Begin with the wood board as your base.
2. Place the two 1ft PVC pipes in each opening of the T-junction PVC joints that are already screwed into the wood base.
3. Take the two PVC elbow joints and place them on the ends of the 6" PVC pipe.
4. Place the assembly from step 3 onto the 1ft vertical PVC pipes.
5. Screw 1 nut onto the 2" eyebolt as far as you can.
6. From the underside of the PVC assembly, insert the eyebolt from step 5 into the pre-drilled hole in the 6" horizontal pipe.
7. Screw another nut on the topside of the eyebolt to hold it in place.

Step 2: Assembling the mass & magnet

8. Next screw a nut onto the 5" eyebolt.
9. Place the 1/4" and 3/8" washers on the eyebolt.
10. Place the two round magnets on the eyebolt.
11. Place the 6 1/2" washers on the eyebolt.
12. Place the 3/8" and 1/4" washers on the eyebolt.
13. Place the last nut on the eyebolt and tighten.
14. Now hang the gray "factory" spring from the hanging 2" eyebolt that you connected to the assembly structure.
15. Lastly, hang the magnet-washer mass assembly from the spring.

Step 3: Assembling the wire coil

16. Using the small plastic container, begin at the top and wrap the double sided tape *around* the top 1-inch of the container.
17. Using the red wire, leave approximately 10" free at the beginning and then begin wrapping the wire around the container along the location of the tape. Start from the top of the tape and wrap down. Try to wrap the wires as close as possible. When you reach the bottom of the tape, wrap in the opposite direction (up) over the wire that you just wrapped (see Figure 2.).
18. Repeat the wrapping up and down of the wire as in step 17 until approximately 10" of wire is all that is left. *Do not cut the wire!*
19. After you have completed constructing the wire coil, tape down the wire coil along one side of the container with regular tape to hold the wire in place.

20. Next, use the piece of sandpaper to sand away the red-colored coating of the wire at the free (loose) ends of your coil. Sand off approximately 1/4-1/2 inch of the wire. Try not to sand too much that the wire breaks.

Step 4: Final adjustments

21. Now it's time to adjust the height of the magnet/spring system. The magnets should hang directly in the middle of the ring of wire coil. Adjust the height of the eyebolt attached to the PVC support structure to make the magnets hang in the correct position.

22. After you have properly adjusted your system, secure the plastic container to the wood base with a few pieces of regular tape.

23. Finally, take your finished seismometer to the oscilloscope that is set up at the front of the classroom. From here, we will hook your seismometer up to the oscilloscope and begin to collect data.

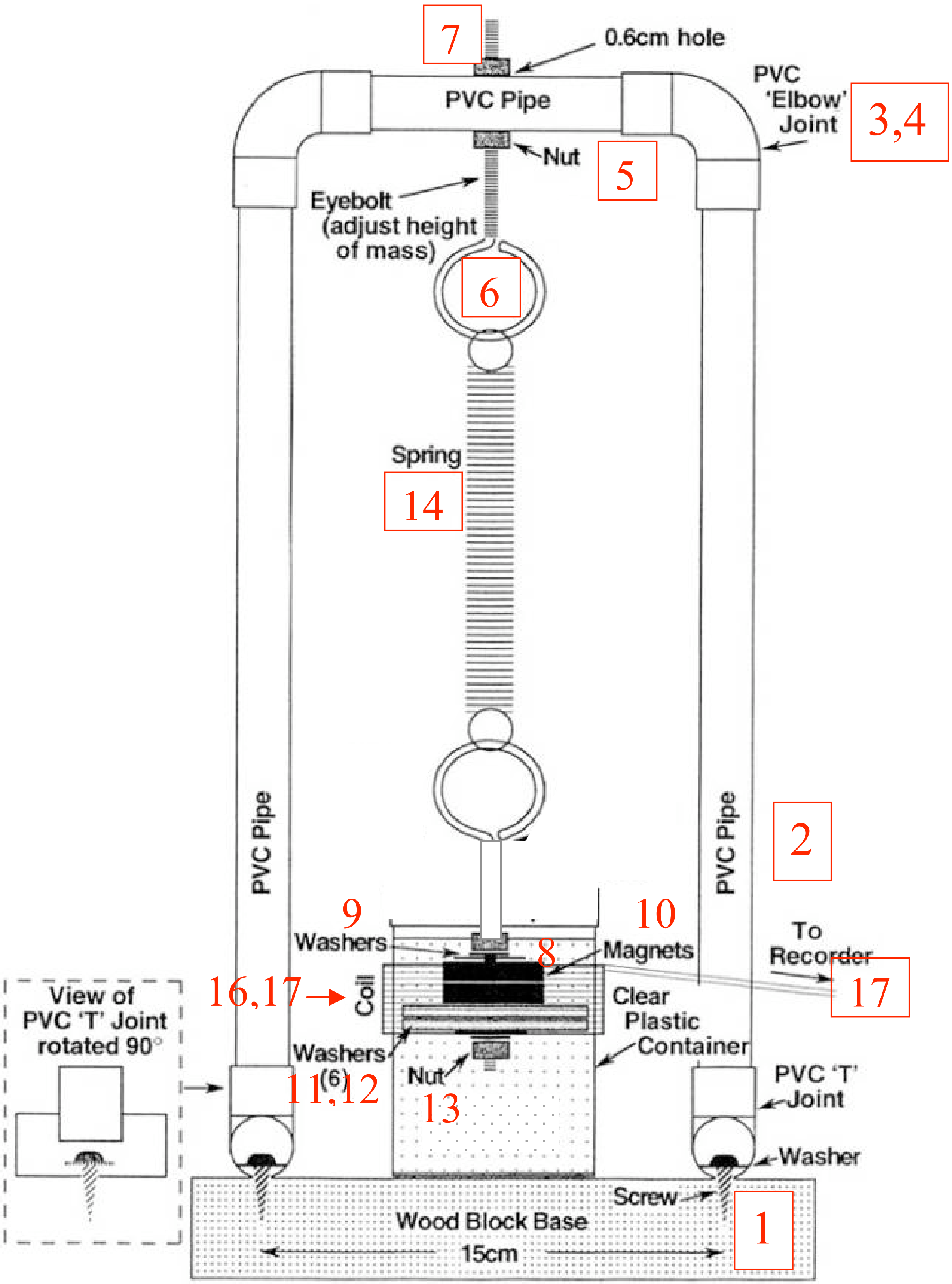


Figure 1. Cartoon sketch of hand-held seismometer. Materials are labeled with numbers corresponding to instruction steps.

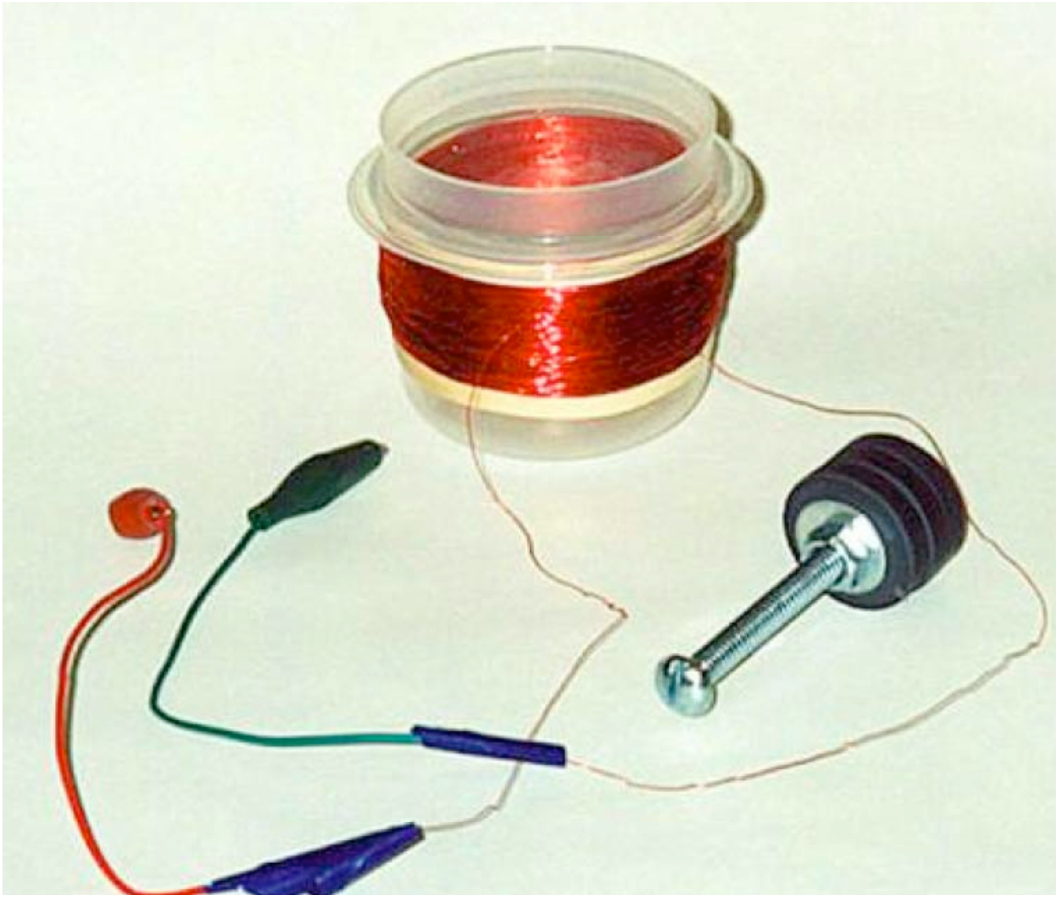
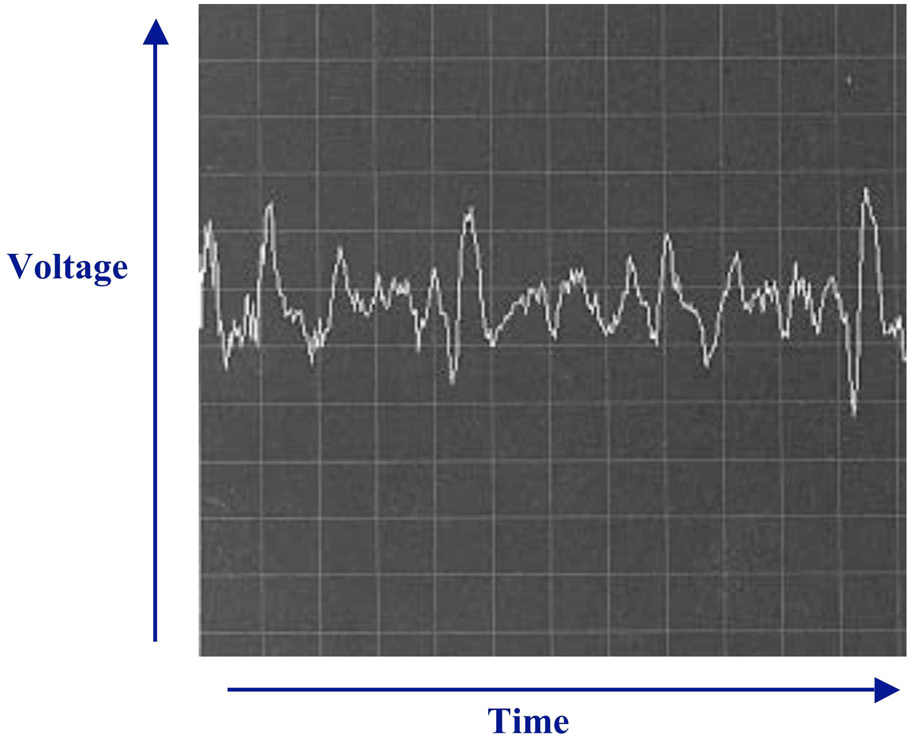


Figure 2. Image of red wire wrapped around a plastic container to form a tight coil. The red and green voltage sensors seen in the image on the left side will not be used in this lab. Instead, we will hook the wire ends of your coil to sensors on an oscilloscope. Also seen in the picture is an example of the round magnets connected to an eyebolt. Your magnet assembly will look similar to this, but not identical.

Experiment 1: Factory Spring + Round Magnets

1.1 Once your seismometer is connected to the oscilloscope, you will begin to observe a signal on the screen of the instrument. The vertical axis of the signal is the voltage and the horizontal axis of the signal is time:



What are the units of time on the oscilloscope? ______________________________

What are the units of voltage on the oscilloscope? ____________________________

1.2 Now hold the spring steady (no motion) and observe the readings of the oscilloscope. Do you observe any unexpected voltage signals on the screen? If so, what might these be caused by?

1.3 Now let the spring bounce up and down.

Does the voltage change?

Why or why not?

Experiment 2: Factory Spring + Rare Earth Magnets

2.1 Now we are going to swap out the round magnet assembly for some very powerful magnets called **Rare Earth Magnets**. These magnets are *extremely* strong and we do not recommend that you handle them (let us!). Once these magnets have been safely attached to your seismometer, allow the spring to bounce up and down and observe the signal.

How is the oscilloscope signal produced by your seismometer affected by the Rare Earth Magnets? Why?

How long is one "division"? ___________

Now count how many cycles you see on the oscilloscope screen, in one division. _______________

What is the frequency of your spring (cycles / second)? __________ Hz

Experiment 3: Home-made Spring + Rare Earth Magnets

3.1 Now you are going to build a home-made spring from the gold wire and see how it behaves compared to the gray factory spring used in the last experiment. To build the home-made spring, wrap the gold wire around a pen or pencil about 20 times. Make the coil tight and leave no space between the wraps. When you are done wrapping you can stretch the spring as necessary.

3.2 Remove the pen/pencil from the wrapped wire – and you have your spring!

3.3 Remove the gray factory spring from your seismometer and replace it with your home-made spring.

3.4 Now bring your upgraded seismometer to the oscilloscope again to test out the behavior of your home-made spring.

3.5 With the Rare Earth Magnets suspended from your home-made spring, move the magnets up and down to illustrate simple harmonic motion. Note that there is a "natural frequency" of the oscillation.

Measure the period (1/frequency) of oscillation and note the sinusoidal characteristics of the signal. Draw a rough sketch of the oscilloscope display.

What does the sinusoidal signal mean?

Is the motion purely sinusoidal (Hint: watch what happens over a long time)?

What do you think controls the period of oscillation?

What is the frequency of oscillation? How does this compare to before?

Experiment 4: Rubber Band Assembly + Rare Earth Magnets

4.1 Now you are going to simulate the up and down motion of a spring by using an assembly of rubber bands. To do this, loop and knot your three rubber bands together to form one long rubber band piece.

4.2 Remove your home-made spring from your seismometer and replace it with your rubber band assembly.

4.3 Now bring your seismometer to the oscilloscope again to test out the behavior of your rubber band spring.

4.4 With the Rare Earth Magnets suspended from your rubber band assembly, move the magnets up and down to illustrate simple harmonic motion. Again, measure the period (1/frequency) of oscillation and note the sinusoidal characteristics of the signal. Draw a rough sketch of the oscilloscope display.

What changes do you notice in the oscillation of the rubber band-magnet assembly? (Is the frequency different? Is the motion purely sinusoidal?, etc.)

Why would a seismometer have a dampening component? (Hint: Watch what happens to the amplitude of the sinusoidal motion over time.) This is Q!

What is the frequency of oscillation? Which suspension (springs or rubber bands) gives the highest frequency? The lowest?

Summary Questions

Based on your observations of the different types of materials used to test your seismometer, which experiment (and materials) performed best?

Based on your oscilloscope observations of voltage behavior, which action of the seismometer is proportional to the output voltage amplitude?

If you let the seismometer just sit on the table, you will notice that there is still some shaking, and therefore a small signal, on the output record. Because there is no specific source (intentional shaking of the seismometer or earthquake–generated ground motion) during this time interval, we consider the output signal to be background "noise." Note that a small tap (a specific source of shaking) on the base of the seismometer may not produce a signal that is visible above the noise that is being continuously recorded. Because of the presence of background noise on the seismograph, small signals or signals from distant earthquakes are sometimes not visible on the seismogram because amplitudes (levels of shaking or height of the signal on the seismogram) of the signal may be smaller than the noise level.

Based on this information, which would be a better location for a seismometer:
A farm in Iowa or someone's backyard off the 5 HWY in LA?