Rotating Lab 4
Vibrating Chladni Plates

Prof. Tunks and Prof. Olness
TBD

PHYS 1320
Fall 2017

1 Introduction

1.1 Free-Form Lab Investigation

The last five labs of the semester are "free-form" rather than "cook-book" style. I provide you the equipment to investigate different phenomena, and you decide how you are going to explore the questions. Many of these labs are new, so I am looking for you to be creative and come up with interesting methods.

Since the equipment for these five labs is specialized and expensive. *Please take good care of the equipment.* I only have one set-up for each lab. This means that for week #1, five teams will be working on five different labs, ant then we will rotate. There will be a sign-up sheet to determine the rotation.

1.2 *Equipment Warnings*

As mentioned above, some of this equipment is hi-tech, and very expensive. Please be very careful; pay attention to all equipment warnings. *If you have a question, please ask.* Anyone who is electrocuted or explodes will receive a failing grade for that lab segment.

- **The wave driver is simply a speaker with a driving rod attached. Therefore, if you place significant force on it when attaching or removing the plates, it will damage the speaker diaphragm, and break the wave driver. Please be very gentle when attaching and removing the plates.**
- **There is a "stop ring" on the shaft of the wave driver. If the voltage applied to the driver is too large, this ring will impact against the metal plate giving an audible warning—immediately reduce the voltage to avoid damaging the wave driver.**

1.3 Required Reading

The following passages from your textbook explain the material for this lab and prelab.

- Other Vibrating Systems p.71-75
- The Percussion Instruments (full chapter) p.299-306

2 Experiment

Find <u>at least</u> three resonances for three different plates including the violin shaped plate. For this lab, the attached instructions are quite useful.

- Sketch the resonance patterns and note the associated frequencies.
- Comment on any patterns or general features that you observe.
- Is there any relation between the resonant frequencies you observe and the harmonic series that we have been studying?
- What other observations or comments can you make?

Instruction Manual

for

EG-54 Chladni Plates

Introduction

One of the most interesting uses for the EG-50 Audio Driver and EG-52 Electromechanical Driver is to use them to excite vibrations in simple, thin metal plates. The plates are attached at the center to the drive post of the transducer. The idea originated with E.F. Chladni (1756-1827) who devised a method for making visible the vibrations of a metal plate. Fine sand sprinkled on the plate comes to rest along the nodal lines where there is no motion. He excited the motion by using a violin bow on the edge of the plate. Bowing requires much greater skill than using the precise, stable frequency of the EG-50 Audio Driver.

The four plates which make up the EG-54 Chladni Plate set consist of a square, a circle, a triangle, and a violin back shape. The simple geometric shapes have easily found resonances and simple nodal patterns at lower frequencies. The vibrations of the square and circular plates can be studied analytically as well. The mathematical derivation of the motion is a little daunting, but it does provide another level of understanding of the experiment. An excellent theoretical treatment can be found in Fletcher N.H. & Rossing T.D. *The Physics of Musical Instruments*, Springer-Verlang, New York (1991) and in a more abbreviated form in the paperback, French A.P. *Vibrations and Waves*, Norton, New York (1971). These analyses largely deal with clamped edge plates because the boundary conditions are simpler to deal with. In this experiment, the plates all have a free edge. Nevertheless, the theory adds a good deal of insight to the understanding of the vibrations.

The violin back is without theoretical model. The plate vibrates in complex nodal patterns, with many resonances. This is part of the reason that the sound of a violin is so rich in overtones and that, when well played, is so satisfying to listen to. In actual instruments, the violin back has a clamped edge, while in this experiment the plate vibrates with a free edge.

Procedure

The circular plate driven at its center produces the simplest resonances. They are similar to drumhead resonances and are axially symmetrical.

1. Attach the circular plate to the top of the Driver shaft with a #4-40 machine screw and a pair of lock washers. When tightening the screw, hold the end of the shaft with pliers to keep it from rotating while tightening the screw.

2. Place the transducer with the plate uppermost on a level table. This is important, because the sand sprinkled on the vibrating plate will slide off one side if the plate is not horizontal. Turn on the Audio Driver and set the frequency to 100Hz and the amplitude about 1/3 from zero.

3. Increase the frequency slowly and listen for an increase in audible sound. The plate radiates much more sound at resonance than in between resonances.

4. When a resonance is found, reduce the amplitude and sprinkle a little clean dry sand onto the plate. The individual

grains will dance on some parts of the plate and lie still at others. Turn up the amplitude a little until a good pattern is found. Sketch or photograph the pattern.

5. Increase the frequency slowly to find the next resonance. As the frequency is increased, the amplitude should be increased a little as well.

The number of resonances found depends upon your patience. The circular plate vibrates with circular nodal patterns until the higher modes are reached. The theoretical modal frequencies are given in Table 3.2 of Fletcher & Rossing.

6. Remove the circular plate and replace it with the square one.

Chladni Patterns

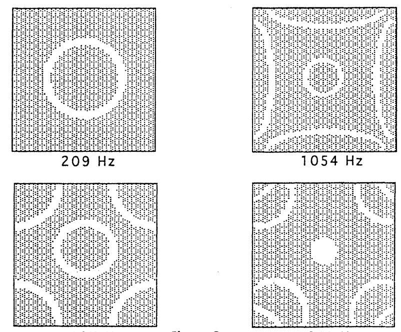


Figure One

7. Repeat Steps 4 and 5 to find the resonances for the square plate. Typical resonances are shown in Figure One. You should be able to find these same patterns, but not necessarily at quite the same frequencies. The frequencies depends upon the thickness, exact size and strength of the metal. Small differences are to be expected.

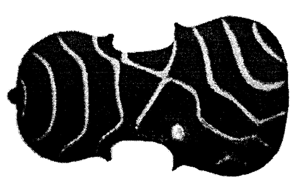
8. Tabulate the frequencies and sketch the patterns as before.

9. Repeat with the triangular plate.

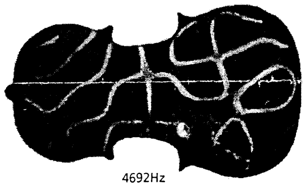
Resonances for a vibrating string are simple multiples of the fundamental frequency. The resonances in plates bear no such simple relationship. These complex harmonic relationships produce the brilliant sound of a cymbal crash where many resonances are sounding together.

The plate shaped like a violin back is designed to attach to the Driver off-center. This mounting position simulated the position of the sound post in an actual violin. This is a small wooden post connecting the top to the back and transmits some of the strings vibration to the back.

The violin plate in this set is a 56% copy of a violin built in London in 1911 by Emanuel Whitmarsh. The frequency of the resonances depend upon the size and the strength of the material, in this case, aluminum versus wood, so that the actual frequencies would occur at much lower frequencies than observed in the experiment. The shape of the nodal patterns should be similar to an actual instrument.



3741Hz



4692Hz

Figure Two

The two pictures shown in Figure Two are taken from photographs of the nodal patterns. The frequency is quite high in these two cases. At lower frequencies, the patterns are much simpler but still more complex than obtained with the simple geometric shapes.

W.R.J. 8.-August 1993