

This project combines science and visual art. I experimented with ways to visualize sound, which is called cymatics. Because sound waves can combine to create what are called standing waves, we can “see” sound. I executed three different experiments that played with this idea. I used an array of different materials for my experiments. This project is mostly about the process of figuring out how to use these different materials to construct the mechanisms that showed sound.

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# Visualizing Sound

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## What is Cymatics and How Does It Work?

Cymatics is the study of sound and vibrations. It focuses on the visualization of sound (Journey of curiosity). Standing waves are what make experimentation in cymatics possible. A standing wave occurs when two waves, of the same frequency and altitude<sup>1</sup>, moving in opposite directions, combine to create one wave that doesn't appear to be moving in any direction. The two waves are composed of an incident wave and a reflective wave, meaning a singular wave that hits a surface and is reflected back onto itself. These are the two waves that, at the right frequency, interfere with each other to create a standing wave. The standing wave is composed of nodes and antinodes. Nodes are points in the standing wave where there is no motion<sup>2</sup>. Antinodes are the points in the wave where lots of motion is occurring. Materials respond to distinct frequencies to create standing waves<sup>3</sup>. These frequencies are called harmonic frequencies. The standing waves are what allow sound waves to be captured in a visual format. They allow us to "see" sound (Singing plates - Standing Waves on Chladni plates).

### Main Contributors to the Foundation of Cymatics

#### Hans Jenny

Named the "father of cymatics," Hans Jenny was the first person to popularize cymatics (Journey of curiosity). Born 1904 in Basel Switzerland, Jenny, though a talented musician, instead chose to become a physician. With his book, published in 1967, titled Kymatic Volume 1, Jenny introduced the world to modern cymatics. He mostly experimented with tone generators and crystal oscillators so that he could control both the frequency and amplitude being played. He believed that cymatics play an important role in the creation of the universe and that it describes many of the patterns in nature (Who was Hans Jenny).

#### Robert Hooke

Though Chladni is most recognized for the creation of chladni figures and the experimentation with chladni plates, he was recreating Hooke's experiments. Hooke had experimented with running a bow along the side of a glass plate that had been covered with a thin layer of flour. He noticed the symmetrical patterns that formed on the plate. Though Hooke is more widely known for his law on elasticity (Who was Hans Jenny).

#### Ernst Chladni

Chladni used Hooke's experiments with a bow and glass plate as a base for his experimentation in cymatics. He used a bow and a brass plate sprinkled with sand for his experimentation. The patterns he noticed on the plates were named Chladni figures (Journey of curiosity). He receives the recognition of this experiment because of his book, Discoveries in the Theory of Sound published 1787 (Who was Hans Jenny).

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<sup>1</sup> Frequency is the length of a wave and amplitude is the height of a wave.

<sup>2</sup> The distance between each node is equal to  $\frac{1}{2}$  the frequency of the wave.

<sup>3</sup> This is because a standing wave is dependent on the timing of regeneration of the incident wave in order to perfectly align with the reflected wave.

Mary D. Waller

Mary D. Waller was a professor of physics at the Royal Free Hospital Medical School in London. She recreated Chladni's experiments and took note of the patterns that she found at certain frequencies. She also developed the mathematics behind these experiments. She published her research in a book titled, *Chladni Figures, a Study in Symmetry* (Journey of curiosity).

## **Chladni plate**

### Introduction

Chladni plates are constructed using a thin metal plate mounted onto a speaker. The plate is covered in a thin layer of sand that forms patterns, or chladni figures, when certain frequencies are played through the speaker. The patterns produced are the result of standing waves. The spots where the sand stands still are the nodes of the standing waves, or points of no motion. In the empty spaces, the sand is vibrating very quickly; these spots are the antinodes, or points on the standing waves where there is lots of motion happening. The higher the frequency played, the more intricate the pattern, because the nodes are closer together on the standing wave.

### Methodology

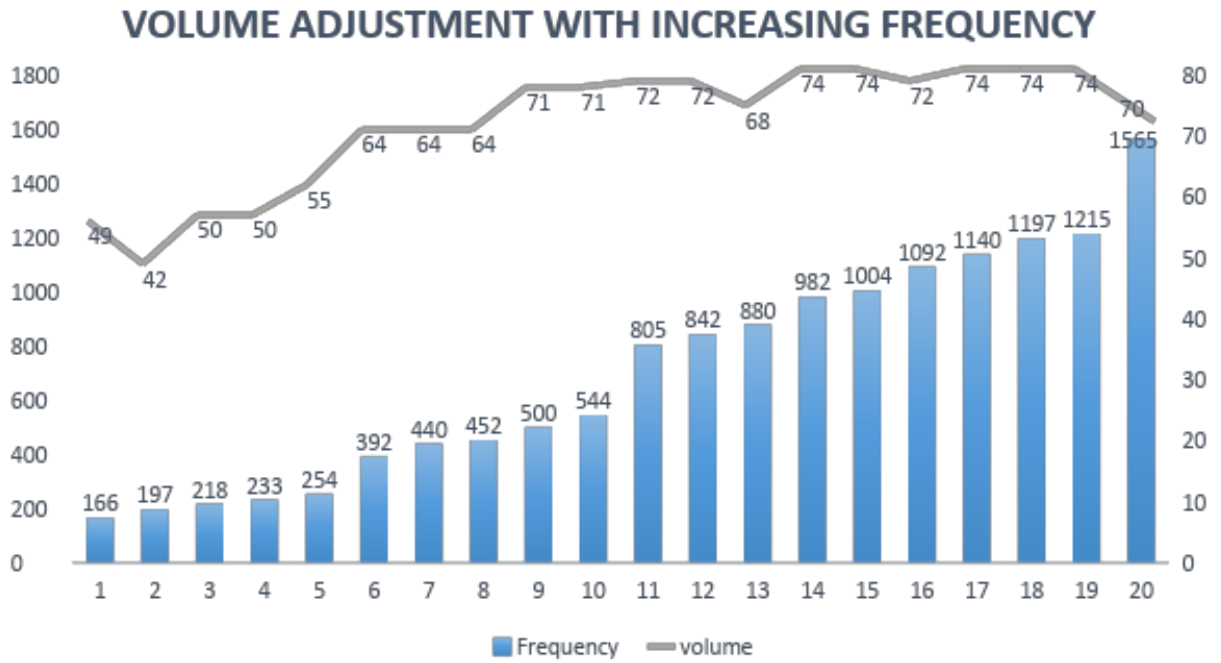
For This experiment, I started by experimenting with various speakers. I used some old TV speakers that I had in my garage. First I broke off the top part of the speaker and un-screwed the two mid-tone speakers from the box. I connected the speakers to my computer and to the receiver we had kept with the speakers. I then collected the rest of the materials. These materials included: a metal plate, bolts, washers, wingnuts, foam, foil cupcake pan, hot glue, sand, and online tone generator. I used a spray foam and the foil cupcake pan as the mold. I had to spray water on the foam so it would cure; this took about 4 hours, including drying time. The next step was to construct the chladni plate. My neighbor helped me out by cutting the metal and drilling holes in the middle of the plates so that I could mount them onto the foam on top of the speaker. To build the chladni plate, I first trimmed the foam down to size and shaped it into a spherical shape with a serrated knife. I poked a hole in the top of both foam pieces and hot glued the bolts into them. I then glued the washers on top of the bolts. I hot glued the foam spheres onto the speakers and secured the plate onto the bolt by screwing the wingnut on top. I then sprinkled sand on top of the plate and started the experiment.

### Results

I tested 20 different frequencies. Table 1 shows the different frequencies and the volume setting utilized. The more intricate patterns were seen with higher frequencies. The highest frequency reached that still produced a pattern was 1,565 Hz. Low frequencies had simple patterns. The lowest frequency reached that produced a pattern was 166Hz. Volume played a role in obtaining a visible pattern. The sound volume had to be reduced for low frequencies. The lowest sound volume used was 42 decibels. Higher frequencies required higher sound volume. The highest sound volume used was 74 decibels. The average frequency was 706 and the average sound volume was 65. Figure 1, is a graph of the frequency and the corresponding sound volume used. Below the graph you will see the figures and the corresponding frequency.

Table 1.

| Figure # | Frequency (Hz) | Volume |
|----------|----------------|--------|
| 1        | 166            | 49     |
| 2        | 197            | 42     |
| 3        | 218            | 50     |
| 4        | 233            | 50     |
| 5        | 254            | 55     |
| 6        | 392            | 64     |
| 7        | 440            | 64     |
| 8        | 452            | 64     |
| 9        | 500            | 71     |
| 10       | 544            | 71     |
| 11       | 805            | 72     |
| 12       | 842            | 72     |
| 13       | 880            | 68     |
| 14       | 982            | 74     |
| 15       | 1004           | 74     |
| 16       | 1092           | 72     |
| 17       | 1140           | 74     |
| 18       | 1197           | 74     |
| 19       | 1215           | 74     |
| 20       | 1565           | 70     |



166 Hz



197 Hz



218 Hz



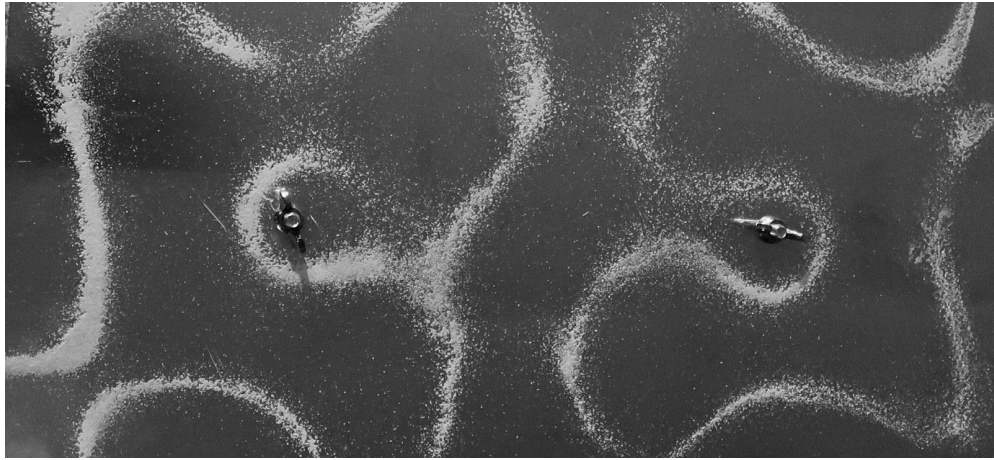
233 Hz



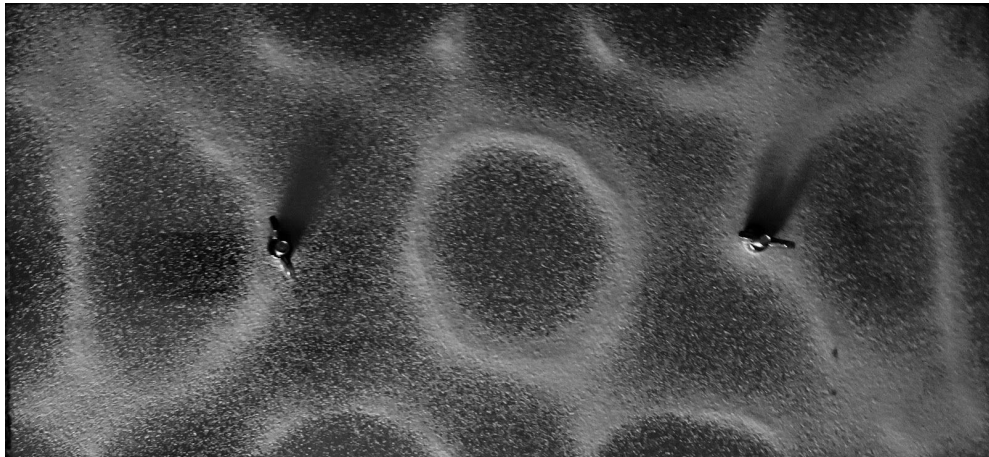
254 Hz



392 Hz

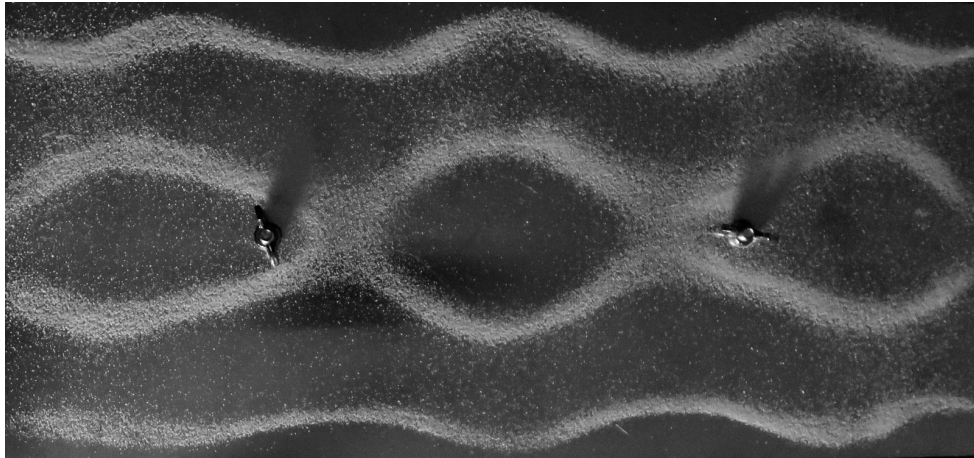


440 Hz





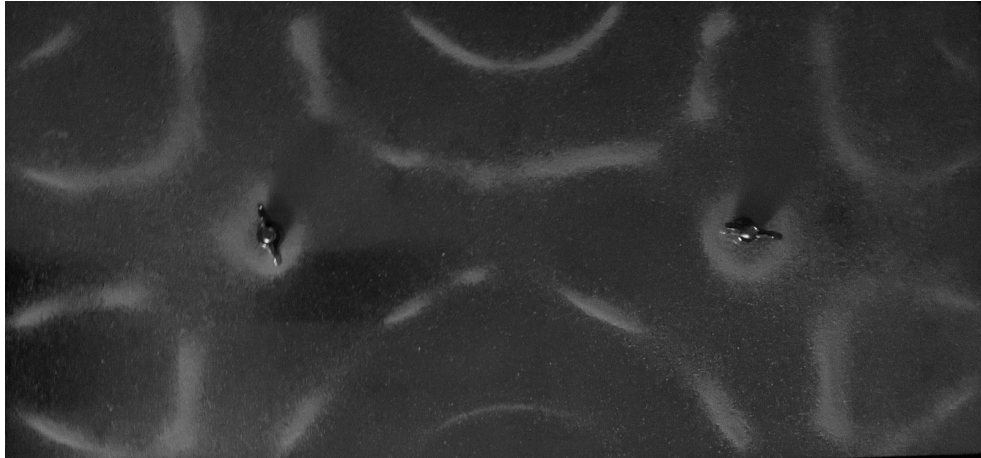
452 Hz



520 Hz



544 Hz



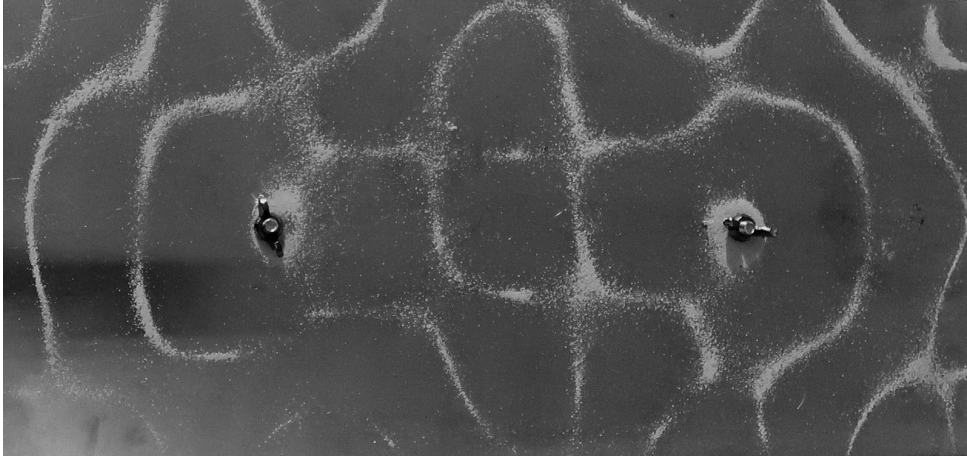
805 Hz



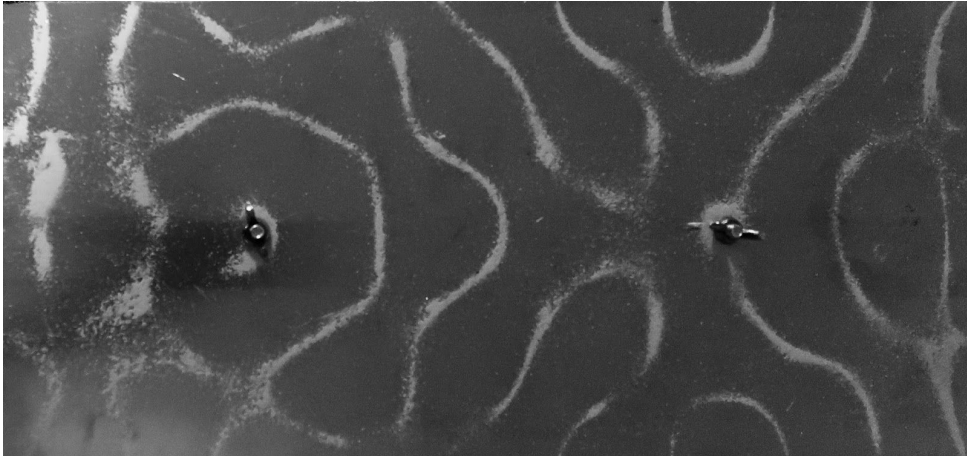
842 Hz



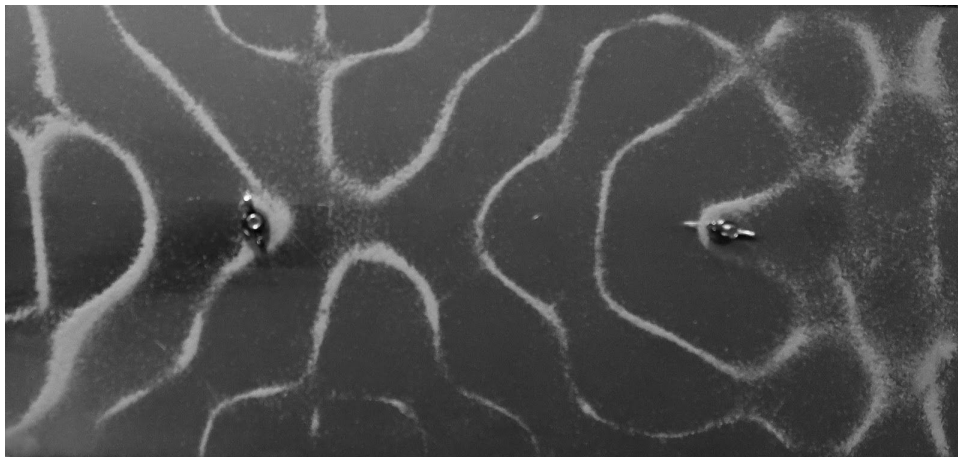
880 Hz



982 Hz



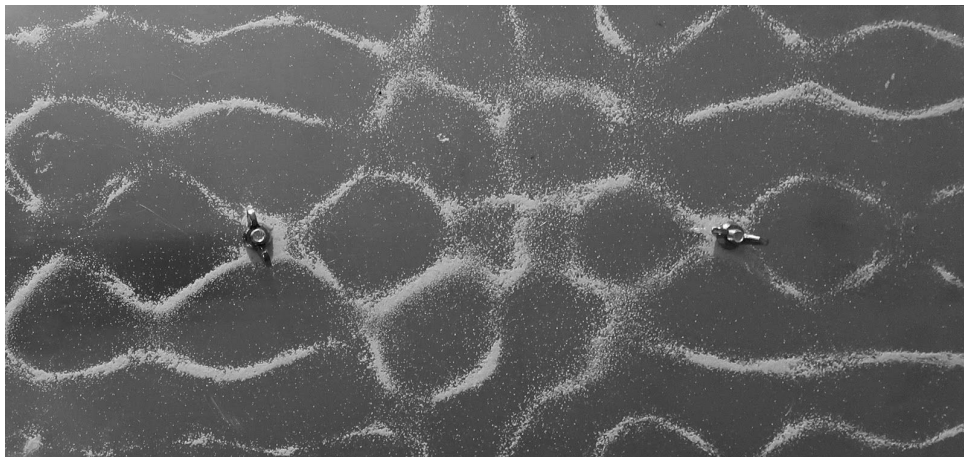
1004 Hz



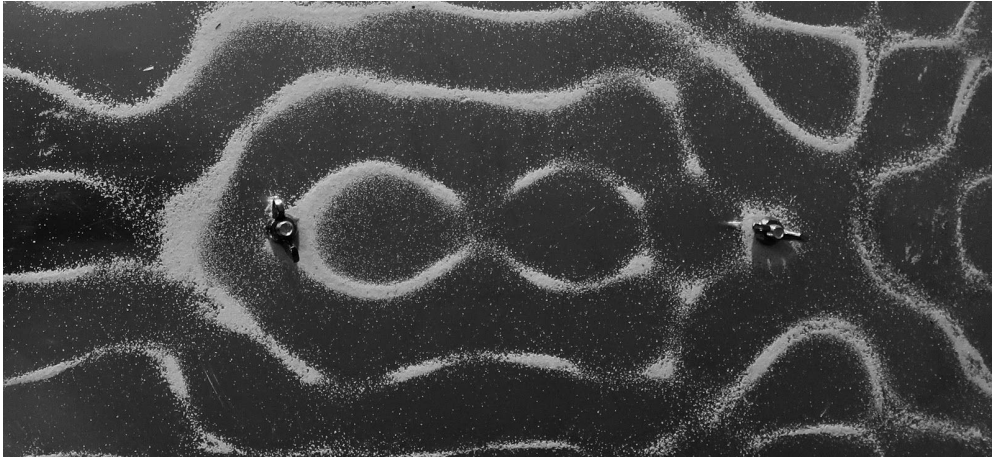
1092 Hz



1140 Hz



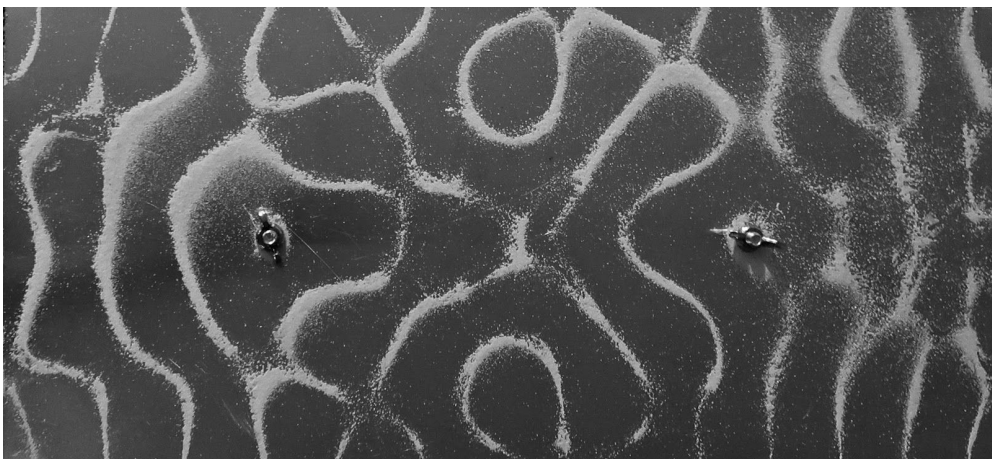
1197 Hz



1215 Hz



1565 Hz



## Discussion

Although the experiments were accomplished, there were several barriers encountered. One barrier was limited knowledge on speakers, wiring, and connecting speakers to the receiver and to my computer in order to generate sound. The majority of the barriers were due Covid-19 limitations such as at-home orders, store closures, limited product availability, busy stores limiting pick up of purchased items, and delays in shipping by most online stores including Amazon. I was able to find most of the materials at Lowe's and at home. Once the chladni plate was constructed and all components were connected, obtaining visual patterns included identifying the correct frequency and the best sound volume. The higher the sound, the more vibration was generated. Too high of a sound for the frequency used would disrupt the pattern that had been created. Too low of a sound for the frequency used would not create the necessary vibration and no visual pattern would be created. Once the ideal frequency and corresponding sounds were identified, visual patterns were captured using still photography. A video of the visual pattern changes created with changes in frequency was captured to help the viewer see the transition between chladni figures.

## Vodka Dish

### Introduction

This experiment uses chilled vodka in a dish on top of a speaker to show still waves. When certain frequencies are played, waves form in the liquid that appear to be standing still. This is the sound waves creating still waves. In other words, two waves going in opposite directions, combine to create a wave that looks as though it is not moving. So instead of a ripple in the liquid that travels from the center out, or vice versa, we can see waves that, are still in the liquid, give and take a little vibration.

### Methodology

For this experiment I started with an old speaker that I had in my garage from an old TV sound system. After finding the right chord, I connected the speaker to my computer and was able to get the speaker to operate. I taped a small circular glass dish to the speaker with masking tape. I then poured vodka that I had chilled in the freezer into the dish. I used chilled vodka because [its viscosity works well for the experiment](#). I was then ready to start testing it out. To test out specific frequencies I used an online tone generator. (<https://www.szynalski.com/tone-generator/>)

### Results

I tested a range of frequencies from 29 Hz to 100 Hz. The clearest standing waves were at 63 Hz and at 72 Hz. 63 Hz required a lower volume than 72 Hz to create the standing wave. This frequency was also able to create two types of standing waves at different volume levels. A lower volume created what can be described as a still ripple and the higher volume level created a pattern that contained many small waves within. The frequencies lower than 63 Hz made the speaker shake too much to create still waves. When I turned the volume down to counter act this, no waves were created in the Vodka. Frequencies higher than 80 Hz created rapid traveling waves with a lot of movement.

This is a video that shows the vodka at frequencies starting at 63 Hz and traveling to 85 Hz.



At 14 seconds we can see the still wave form at 63 Hz. Though the light makes it look as though it is moving, the vodka is barely vibrating in the wave form. At 29 seconds we no longer have a still wave. Again at 50 seconds, a still wave forms and at 1 min 4 seconds the wave has changed. At 1 minute and 6 seconds we see the rapid waves mentioned above.

This is a close up of the still wave at 63 Hz



### Discussion

The difficult part of this project was actually the documentation. It was harder to capture a still wave than I had anticipated. I tried different lighting yet every time the reflection of the light in the liquid makes the wave look like it has a ripple effect. The vodka is still vibrating, it is not absolutely still just not moving in a particular direction, and the reflection of the light was moving with the vibration causing a problem when filming. I tried my best to find certain angles that could help show the true wave but I think that it is still a little hard to see in the videos.



## **Laser Experiment**

### Introduction

This experiment is a little different than my other experiments that had a little more to do with a particular type of wave. This experiment is more focused on vibrations in general. This is an experiment using a plastic tube or container, a balloon, a small mirror, a laser pointer, and some sort of mount for the container. There are different ways to execute this experiment, but in my case, I used a container that was open on one end and closed at the other end. A speaker was placed inside the container with a balloon stretched over the open end. A mirror was taped onto the outside of the balloon. A laser was pointed at the mirror at a bit of an angle. The laser light that reflected should be pointed at a wall. When sound is played through the speaker, the vibration of the balloon causes the laser to “draw” on the wall; thus allowing for sound to be visualized. When you play music through the speaker you’ll most likely get what looks like a big scribble on the wall, but when you play pure tones or frequencies you can see distinct clean shapes. For example, different variations generate ovals. The reason for this is easy to see if you picture the movement of the balloon. Picture the membrane moving in a back and forth motion, it would create a line with the laser. Now add a little bit of motion in the opposite direction to create a more circular motion. This is what causes ovals to appear. The width and length of the oval depends on how much the balloon vibrates in each direction.

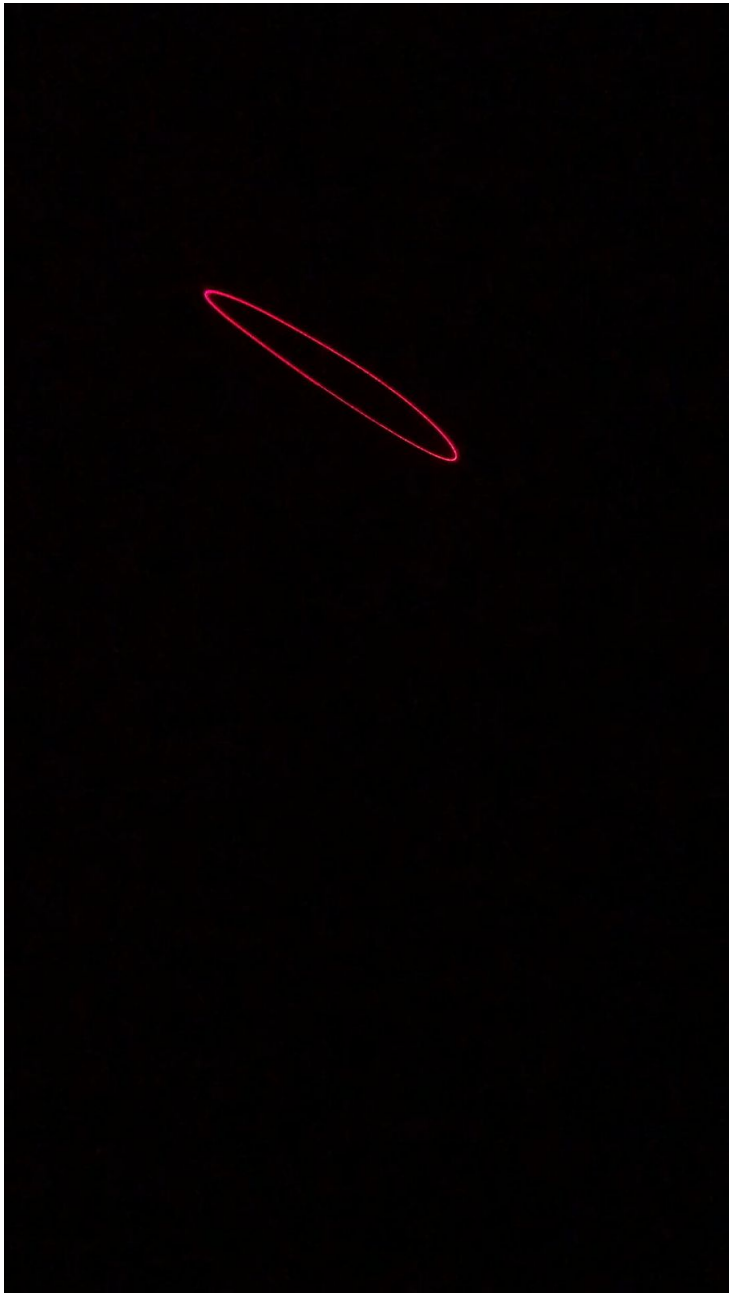
### Methodology

The materials for this project include: a plastic container, a smaller Bluetooth speaker, a balloon, hot glue, a laser pointer, wood for the mount, a small mirror, and an online tone generator. For the mount, I used large wooden popsicle sticks and paint mixing sticks. I glued the mixing sticks together for the base then glued together smaller pieces of the popsicle sticks that I had cut up as a mount for the plastic container. I then glued the container to the mount. I set a Bluetooth speaker inside the container and covered the open end with the balloon, and taped the mirror onto the outside of the balloon. I then played music or frequencies through the speaker to vibrate the balloon. I pointed the laser towards the mirror and made sure the reflection pointed towards the wall. I captured still photos of the designs created.

### Results

I tested a range of frequencies from 730Hz to 37Hz I started by simply sliding through these frequencies and observing the shapes change.

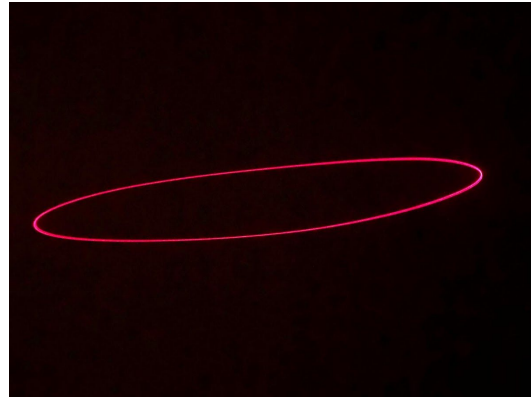
This is a video of the laser with a range of frequencies from 200 Hz to 730 Hz.



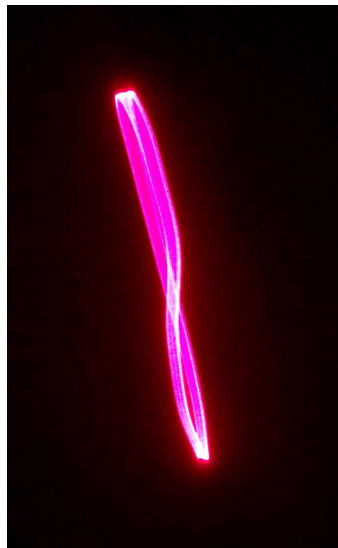
I then repeated this but stopped at the frequencies that I believed created the most interesting shapes. I isolated 5 frequencies from 362 Hz to 67Hz.



362 Hz



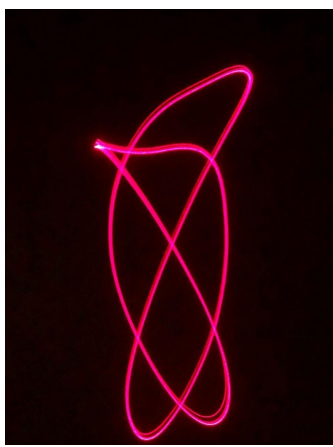
109 Hz



149 Hz



118 Hz



67 Hz

## Discussion

After testing the different frequencies, I decided to have a little fun and tested the laser out with songs from different genres of music. The songs I used were Ya Tú Sabes- CNCO, Cometa- CNCO, Mozart symphony No. 40, Happy Does- Kenny Chesney, Ocean- Karol G, and Bad Guy- Billie Eilish. It was mostly just scribbles, but the patterns were still really interesting and a few circles did show up. Overall, this experiment was more complicated than I had anticipated. The first problem arose in finding a laser pointer. No local store carried them and online stores would not deliver until the end of May. I ended up borrowing one from my mom's work friend. The mirror also proved difficult to find because of the lack of open craft stores and delays in shipping non-essential items. I had to break open a make-up compact and take the mirror out of that. Balloons were also hard to come by. Grocery stores did not have them and although I found them at Walmart, when I drove there to pick them up, the employees were too busy and could not bring them to me. I finally found one pack at Walgreens. I cut the closed end of the first container. I cut the small end of the balloon off and stretched it across one of the open sides of the container. I taped the small mirror to the outside of the balloon and shined a laser too test it out. I tried to talk into and play tones through the open end of the container, but the open end of the container turned out to be too big and did not generate a strong enough vibration to shake the balloon, so I had to try something else. I then got a second container, I connected my computer to the speaker, I placed a Bluetooth speaker in the container, I placed the balloon on the open end of the container and taped the mirror to the balloon. I then hot glued the container to the wooden mount and this generated enough vibrations to create visual images on the wall when I shined a laser into the mirror while playing tones.

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