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Instructional Guide

Chladni Plates Kit

Part# P7-1500-04

Contents:

1 Square 24 cm Plate
1 Round 24 cm diameter Plate
2 banana plug connectors
1 Allen Key
1 Bottle with extra-fine sand
1 Shaker bottle (empty)

Required but not included:
Sine Wave Generator
Mechanical Wave Driver

Teacher's Background Knowledge

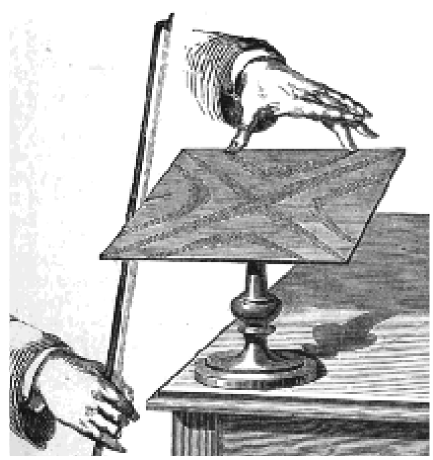
The Chladni Plate (said like the words "clawed knee") was a device experimented upon and whose theory was described by Ernest Chladni (German Physicist 1756-1827). The plates are able to vibrate with several harmonic frequencies and display patterns. It is a lesson in standing waves in two dimensions; vibration in the plate sets up a pattern based on the frequency and how it is reflected at the ends. However, not every frequency causes a pattern because not every wavelength fits on the plate. Unlike strings (such as guitar, piano, or violin strings) these plates vibrate at a great many more frequencies. Therefore, when struck, they sound more like a gong or a bell. Two-dimensional instruments are not usually used to play a single note and the "gong" sound of hitting a two-dimensional object is what we hear when several of the frequencies sound together. (If all frequencies are present, the sound is more like a drum, or the sound one gets from hitting a wall.)

The lesson is that resonances occur at different frequencies and that there are several possible. This is an important lesson in the Physics of Sound because violins, guitars, and pianos have to take these resonances into account in the shape of their bodies.

If you are going to reference standing waves, it is important to note that the end points are anti-nodes. You will notice that the sand never builds up along the rim of the plates because that is the location where the wave is vibrating the most. This is different from guitar strings because the ends are nodes; the process is to waves on a hanging string or waves in a double open instrument, such as an oboe, pan's pipe, or boomwhacker

Introduction to the Apparatus

Originally the plate was driven with a violin bow. This method has its downsides, because it can be difficult, limits your frequency options, and requires a lot of practice. Today, most often the Chladni Plate is vibrated with a mechanical driver.
You will also need a signal generator to select frequencies and white sand to see the patterns.



An early illustration of a Chladni Plate. Note that the thumb and fingers are used to help place the nodal lines where little movement occurs.

To start, secure the metal clip through the plate and attach it to the Mechanical Driver shaft. The connection must be very secure to transmit the vibrations faithfully. This will oscillate up and down at various frequencies. Different plates are slightly different, but a medium amplitude should work for most resonances. Several patterns will be produced. These standing waves are made visible with sand because the vibra-

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tions are largest at the antinodes which pushes the sand away toward the places where the vibrations are smallest, the nodes, or "nodal lines" because they are in 2D.

Getting Familiar / Experimenting

It is helpful to secure the drive shaft and use medium amplitudes as you search for resonances. Add a small amount of sand until you think you have found one. A larger amount of sand may change the effective mass of the plate and cause the frequencies to vary. Try to balance the plate and driver so that little sand pours off the edges.

The lower frequencies are further spaced, but the higher frequencies can be more complex and beautiful.

Observations and Taking Data

The speed of sound can be measured in the plate itself. Find the frequency from the driver and then measure the wavelength as a node to node (sand to sand) distance.

A reasonable question to discover is "Is the Speed of Sound Constant in the Plate?" The reason that the speed of sound might not be constant is that at higher frequencies and higher amplitudes, the plate vibrates non-linearly. (This is similar to how a prism separates light by color; the speed of light waves are different at different frequencies.)

However, in the plate, the effect can even be complicated more by the damping of the wave. A wave that is vibrating in a medium that reduces its amplitude measurably as it travels is said to be "damped." A good example is how a guitar string will vibrate for a long time after being plucked, unless you put your finger on it, which causes it to dampen out faster. Also, some bells dampen faster than others. Higher frequencies tend to dampen more quickly, too.

If several students are performing the experiment, it might be a good idea to have the students take pictures of the various patterns they produce and note the frequency. Then they can create a (digital) portfolio of their results.

Measuring with the round plate should generate results that are more faithful to the "speed of sound is constant" model. This will be visible in the nodes (white stripes) being equally spaced.

Conclusions

The Chladni Plate provides an opportunity to teach an advanced concept in the Physics of Sound while at the same time performing a demonstration that is visually stunning. The idea of nodes and antinodes (and the idea that these reveal wavelength) should be emphasized throughout the lesson.

A common missed opportunity is to quantify this experiment, and reinforce the v=f formula. The details of the Chladni rules may only serve to over complicate this demonstration, but might be appropriate in an advanced class on the Physics of Sound. (See references for more details on these.)

Bio/About the author

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James Lincoln teaches Physics in Southern California and has won several science video contests and worked on various projects in the past few years. James has consulted on TV's "The Big Bang Theory" and WebTV's "This vs. That" and the UCLA Physics Video Project.

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