Activity Outline: Chladni Plates

Overview
A Chladni plate is a simple tool for demonstrating concepts relating to vibration, frequency, and nodes. It is simple to construct and use, and produces a visually striking demonstration. Chladni figures (the visible patterns of nodes created when the plate vibrates) can be used to teach basic concepts of sound and vibration, or to illustrate the mathematical concept underlying their behavior. The visual appeal of the demonstration is so great that it may also be useful for catching or retaining the attention of a physics-shy audience.

[Image: Chladni figures]

Materials
This Make Magazine article explains how to build an electronically controlled Chladni plate.

This UCLA article explains how to build and use a manually controlled plate by exciting antinodes with a bass bow.

Complete electronic plate kits can be obtained from various vendors for around $40. Pasco Educational offers a kit, a quote for which can be obtained here.

Teaching Concepts
The Chladni plate creates a visually appealing demonstration of the complex nature of vibration, and of the differences in activity as a single surface vibrates at different frequencies. By using a speaker coil to control the vibration of the plate it is possible to produce more patterns and to control them more precisely.

Additional Terms and Concepts
- Vibration
- Frequency
- Node
- Antinode
- Chladni figure
- Harmonic
- Resonance
- Standing wave

Further Reading
UNSW article on the use of Chladni-style techniques in instrument building
Plate vibration in violin construction

HPS CAM article

Pasco kit manual
Chladni Plates Lesson 1: The Bowed Plate

A bass bow is used to produce various figures on one or more Chladni plates, illustrating the concept of nodes and antinodes.

Materials

• Chladni plate
• Bass bow
• Rosin
• Salt

Student Level

Grades 6-12

Terminology

• 2D Vibration
• Frequency
• Node/Antinode
• Chladni plate
• Chladni figure

Suggested Plan

Locate the plate(s) such that the students can easily see their surfaces. Preface by explaining who Ernst Chladni was and his contributions to the plate experiment. Explain that you will recreate his experiment using his original technique, using a bow to create vibrations in the plate.

While the bow technique makes it harder to link patterns to specific frequencies, it has the advantage of overcoming another likely source of confusion: The perception that electronic equipment is essential to producing patterns at all. Producing the patterns without electronic equipment is also more surprising and “magical” in appearance. The essence of the demonstration also remains the same, with the lines formed in the salt indicating non-vibrating nodes within the complex activity of the plate.

This article from UCLA explains the required technique in detail. You will need both hands to produce the patterns. Make sure that your bow is generously rosinized and
that the hair is properly tensioned; you’ll want it fairly loose, but experiment to find what works with your plate.

The major challenge of this demonstration is that the audience needs to be able to see the surface of the plate, which must be parallel to the floor. Attention to seating arrangement and working surface are important. A large mirror or camera and projector can make the experiment visible to larger crowds. When making these decisions, bear in mind that the vibrating plate will propel some quantity of salt in all directions. It helps to plan for cleanup in advance.

[Image: Original Chladni figures]

**Related Concepts**
- Vibration
- Frequency
- Harmonic
- Interval

**Extensions**
Older students can be invited to attempt the demonstration themselves. One option would be for them to conduct the experiment individually or in groups while recording their findings, and compare results later to see if the data matches.

Advanced students may benefit from viewing the demonstration in the context of the wave equations used to predict the effect.

One simple way of extending the demonstration is to incorporate plates of different shapes, dimensions or materials.

**Additional Resources**
- [SMU Chladni Plates page](#) (video and text)
- [Demo of bowed plates](#) of different sizes and shapes
- [Gallery of antique plates](#), useful if you want to build your own
- [Pasco kit manual](#)
Chladni Plates Lesson 2: The Electronic Plate

One or more electronic Chladni plates are used to show a variety of figures and the frequencies that produce them.

Materials
- 1 or more completed electronic Chladni plates
- Salt

Pasco electronic Chladni plate kit

Student Level
K-12

Terminology
- 2D Vibration
- Frequency
- Node/Antinode
- Chladni plate
- Chladni figure
- Oscillator

Suggested Plan
Locate the plate(s) such that the students can easily see their surfaces. Preface by explaining who Ernst Chladni was and his contributions to the plate experiment. Also explain how the plates are controlled by the oscillator and speaker coils. Then produce the figures.

One advantage that the electronic plate has over its bowed counterpart is that you can more clearly show how the figures emerge at specific points on the frequency spectrum. Because you are using an oscillator, it is easy to show the students the relationship between frequency and figure—a relationship that is equally important but less obvious if using a bow.

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projector can make the experiment visible to larger crowds. When making these
decisions, bear in mind that the vibrating plate will propel some quantity of salt in
all directions. It helps to plan for cleanup in advance.

[Image: Original Chladni figures]

**Related Concepts**
- Vibration
- Frequency
- Harmonic
- Interval

**Extensions**

*Chladni’s law*

Note on the Rosslyn Chapel: Though interesting, the historical claims are dubious at
best and *not part of any widespread historical consensus*.

**Additional Resources**

Exploration of *two-dimensional wave equations*

*Student paper* with (dozens of) equations and historical overview

*Pasco kit manual*
Chladni Plate Lesson 3: Equations

Square and round Chladni plates are used to provide context and subject for the equations that explain the figures. Students can then attempt to reproduce Chladni’s and one another’s results.

Materials

- One or more functioning electronic Chladni plates
- Powder for plates (no finer than table salt)
- Visual aids and handouts of formulae

*Pasco Chladni plates kit*

Student Level

9-12

Terminology

- Vibration
- Frequency
- Wave
- 2D Vibration
- Chladni’s law
- Wave equation
- Boundary condition
- Node/antinode

Suggested Plan

Begin by demonstrating the figures again for context. You may want to display the drawings produced by the original experiment:

[Image: Original Chladni figures]

Side note: In addition to publishing his landmark experiment with the plates and advancing the mathematical understanding of two-dimensional vibration, Chladni was also one of the first scientists to propose that meteorites were extraterrestrial in origin.

*This Davidson Physics page* contains a great deal of in-depth analysis of Chladni’s law, including experimental data testing the original hypothesis.

The law itself is expressed as follows:

\[ f = C (m + 2n)^p \]
Thomas Müller’s article about his program NumChladni gives a great introduction to the tool (an interactive eigenmode locator), as well as supplying an exhaustive and clearly-rendered set of equations, including Bernoulli’s solution to the wave equation.

While the mathematics of 2D vibration can be taught in isolation, the concrete example and conceptual aid of the Chladni plates will likely be of great help to many students. The demonstration serves as evidence that even complex and abstract math can (and does) have meaning in the physical world.

**Related Concepts**

Trinity Math has a thorough guide to two-dimensional wave equations.

**Extensions**

If in-class experimental results differ from historical records, try to figure out why. The experiment can also be conducted by multiple small groups of students and their results compared against one another’s as well as their own predictions.

**Additional Resources**

Lab notes detailing construction, mathematics, and experimental results

Pasco kit manual