Chladni Plates: Violin Bow Version

Number of Participants: 2 - 30

Audience: Middle (ages 11-13) and up

Duration: 5-30 mins

Difficulty: Level 3

Materials Required:

The classic way to set a Chladni plate into motion is by using a violin bow, originally done over 300 years ago.

- ¼” thick aluminum or steel plate (with center hole)
- 8” C clamps (2)
- Violin bow
- Rosin for bow
- 5/8”x5/8” square wooden dowel at least 1’ long
- 1/4” bolt with 2 nuts
- Sand or salt

Setup:

1. Gather all materials listed above, as shown in Figure 1.
2. If the metal plate is not pre-drilled, drill a clearance hole (13/64’’ or 7/32’’) in the center of the plate. Lightly file rough edges.

Figure 1 Materials required to set up a Chladni plate with a violin bow. Pictured is a 1/32" violin bow.

3. Attach plate to square dowel as shown in Figure 2.
4. Clamp down square dowel to table using C clamps.
5. Sprinkle sand on plate. Use the violin bow to play the vibrating plate. Note that where the plate is bowed, that location is forced to become an antinode.
6. Bow plate in various locations to reveal different patterns. Lightly touch the metal plate to force nodes in other locations.

Figure 2 Attach the square dowel to the plate. It should be on tight enough that the plate is firmly in position.

Presenter Brief:

Understand sound waves, resonance, vibrations, and normal modes.

Vocabulary:

- Longitudinal waves – waves with excitations parallel to their direction of propagation, e.g. sound waves.
- Anti-node – point of highest amplitude and movement.
- Node – point of zero wave amplitude, or zero movement. Every point on a wave is moving except for the node.
- Resonance – a condition where the frequency applied to the system is the same as the system’s natural frequency.
- Restoring Force – a force that acts in the direction that restores the system to its equilibrium position.
- Simple harmonic motion – the restoring force is proportional to the displacement. The period is independent of the amplitude of vibration.

Physics & Explanation:

Middle (ages 11-13) and general public:

E.F.F. Chladni was a Hungarian physicist and musician who spent the late 1780s and 90’s publishing literature and lecturing physics around Europe. His signature demonstration was sprinkling powder or sand onto a glass plate, and then setting the plate into vibration with a violin bow, creating patterns in the sand. The patterns created are called Chladni patterns, and the setup is named after him (in accordance with Stigler’s law, Chladni was not the first to do the demo; Robert Hooke did 80 years previously).

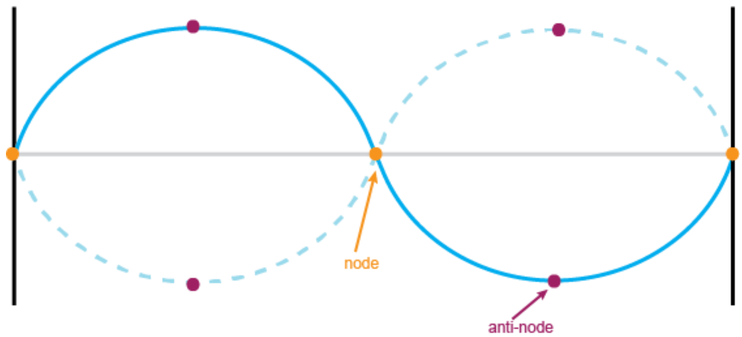

Figure 3 Wave on a string, showing nodes and anti-nodes.

The patterns are a product of waves moving sand on the vibrating surface. Just like waves on a string, the plates have nodes and anti-nodes for a given resonance. In places where there is no surface motion the sand will not be disturbed and collect, while other areas will cause the sand to move into these low motion, or nodal, lines.

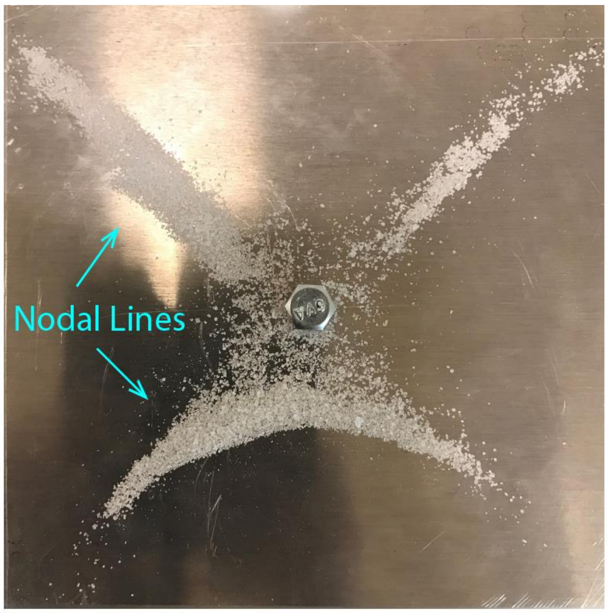

Figure 4 For the plate, anti-nodes are hard to distinguish, since all places on the plates are moving somewhat except the nodal positions.

Sand on the plate is agitated by the vibrations and will tend to collect along nodal lines, where there are no vibrations.

In this setup, you can think of the vibrating plate like its own instrument that you play with a violin bow. Sprinkle sand on the plate, and play the rosined violin bow on the edge of the plate. When a strong resonance is established, patterns will be made. Many frequencies are introduced at once using a violin bow, unlike the frequency generator + speaker method. Which patterns (resonances) that appear will not only depend on the geometry of the plate, but *where* on the plate you play the bow. An antinode is forced wherever the violin bow is placed, in the same fashion that a node is forced on whatever fret you press your fingers down to on a guitar string.

Figure 5 Multiple Chladni patterns created with violin bow. Blue dots mark the spot where the bow was played.

Nodal lines can be forced by placing the violin bow and/or finger in various places.

All waves transport information and energy, without actually moving material (such as water waves in the ocean). In the case of the Chladni plate, the violin bow creates longitudinal sound waves which vibrate the air and we hear as sound. The transverse mechanical waves on the plate move the sand grains up and down into nodal lines. Many forms of kinetic energy are exhibited: compression/rarefaction of air, sand motion, and deformation of the plate.

Waves transport energy.

> Optional discussion topic: what would happen if you played the Chladni plates in space? Would you still see the patterns? Would you hear the sound?

Sound waves need a medium to travel in, so you won't hear sound in space (contrary to all those sci-fi space explosions). Mechanical waves also need a medium to propagate through, regardless if they're transverse of longitudinal. So, if an instrument such as the Chladni plate got put in space, you wouldn't hear the sound, but the sand particles would still move. Since there's no gravity, the pattern would be less pronounced; the sand would just be accelerated off the plate rather than move over into the nodal positions. Now if we made the particles magnetic…

The sand is a means of visualizing an already existing phenomenon. These types of patterns, or cymatics, can be found in numerous places, including: the earth during earthquakes, the surface of the sun, drum heads, cymbals, bells, and any other musical instrument. Scientists use this same idea of looking at Chladni patterns for things such as creating violins, to look at the patterns of different notes, analyzing if the symmetry is there, indicating the desired sounding harmonics. It's called hologram interferometry.

There is an intricate relationship between harmonic sounds and symmetry, and these patterns can tell us useful information.

Additional Resources:

- Rossing Moore & Wheeler *The Science of Sound* 2002.
- Illustrations of wave motions including simple longitudinal, transverse, and water waves https://www.acs.psu.edu/drussell/demos/waves/wavemotion.html