



Making Music Physics Lab

Submitted by: Sheri Caine, Physics
H.L. Richards High School, Oak Lawn, Illinois

Target Grade: 10-12 Physics

Time Required: Approximately four 50-minute periods

Standards:

- NGSS Standards:
 - HS-PS4-11: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
 - MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
 - MS-ETS1-2: Evaluate competing design solutions using a systemic process to determine how well they meet the criteria and constraints of the problem.
 - HS-ETS1-3: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
 - HS-ETS1-4: Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.
- Common Core Standards:
 - F-TF.5: Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline
 - G-MG.3: Apply geometric methods to solve design problems (e.g. designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios)

Lesson Objectives:

Students will:

- create a 3-D printed wind instrument using the MakerBot app.
- be able to predict and find the natural frequency of the sound waves produced by the created instrument.

**Central Focus:**

The students will design a wind instrument that will be 3-D printed. Using the instrument and their prior knowledge of waves, students will predict the natural and fundamental frequencies of the waves produced by their instrument.

Background Information:

- Students will know the basic properties of waves including:
 - Longitudinal v. transverse waves and the flow of energy in each
 - Parts of waves (crest, trough, amplitude, wavelengths)
 - Low energy wave v. high energy wave and the amplitude differences in each
 - Basic understanding of how different types of waves are produced and how waves travel through different types of media.

Materials:

- iPad or equivalent 1-to-1 devices
 - Physics Classroom simulations
 - MakerBot app
 - n-Track Tuner (free) app
 - Keynote app
 - iTunes U app
 - pencil
 - Making Music Lab sheets (attached)
 - Grading rubric (attached)
- 3D printers

Instruction:

Warm-up: (approximately 5-8 minutes)

- The teacher will review properties of waves (e.g., frequency) using the teacher's preferred method/resource for warm-up activities.

Lesson Introduction: (approximately 2-3 minutes)

- The teacher will inform students on the standards, purpose, and learning expectations for the lesson/lab (found on the **Making Music Lab** sheet).

Main Lesson: (approximately four 50-minute periods)

- Students will begin with a wave simulation at <http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Standing-Wave-Patterns/Standing-Wave-Patterns-Interactive>



- Students will follow prompts and directions on the **Making Music Lab** sheet and record answers for each question that follows.
- Once that section is completed, students will download the MakerBot app on their iPad or comparable device at <https://itunes.apple.com/us/app/makerbot/id881138579?mt=8>
- The students will then design the instrument to the specifications stated on the **Making Music Lab** sheet in the **Design you wind instrument** section.
- Once the design is complete, students will request approval from the teacher for the design (teacher will initial the students' lab sheets).
- Students print once the teacher gives the approval.
- After printing, the students will complete #8 and #9 in the **Calculate the frequencies you instrument should play** section of the lab sheet and record their answers in the appropriate areas on the lab sheet.
- When students complete #8 and #9, they should have a peer buddy/partner check their answers and work.
- Once the peer check is complete, students will download the n-Tracker Tuner app <https://itunes.apple.com/us/app/n-track-tuner/id409786458?mt=8>
- Once the download is complete, the students will follow the prompts in #10, a-c and record their answers and then complete #11 and record their answers.
- The students will then complete the **Present your instrument** section of the lab sheet.
- A gallery walk of all students' presentations will be conducted once every student has completed their Keynote presentation.
- After the gallery walk is complete, students will individually complete the **Evaluate & reflect** section of the lab sheet, making sure to include all of the necessary components for assessment purposes.
- Students will then turn the appropriate documents and presentations in to be assessed by the teacher.

Extension Activity:

- **For students who finish early: Students may participate in the **Multicultural extension** section of the lab sheet (if no global partner is assigned, the student may partner with another early finisher and go to this website: <https://folkways.si.edu/ella-jenkins/jambo-and-other-call-and-response-songs-and-chants/childrens/music/album/smithsonian>)
- Each student will choose a track and listen to the free sample, attempting to recreate the songs with their instruments.

Differentiation:

- The lesson's lab sheet provides plain text and visual cues for students.
- Students may choose their individual instrument design with parameters of instructions given.



- Frequent peer and teacher checks throughout the lesson are required.
- Lesson provides practical application with observable evidence
- The gallery walk allows kinesthetic and visual learners opportunities to move around and see other students' creations.
- The personal evaluation and reflect allows student to extend beyond their original ideas and existing work.

Assessment:

Formative:

- Teacher approval of instrument design (teacher's initials required)
- Teacher circulating the room, checking the calculations of students in #8-#11
- Peer assessment of calculation problems
- Self-reflection of the lab and other students' work

Summative:

- Keynote presentations created by students (using grading rubric)
- Completed lab sheets (using grading rubric)

Name: _____ Period: _____ Date: _____

Making Music Lab

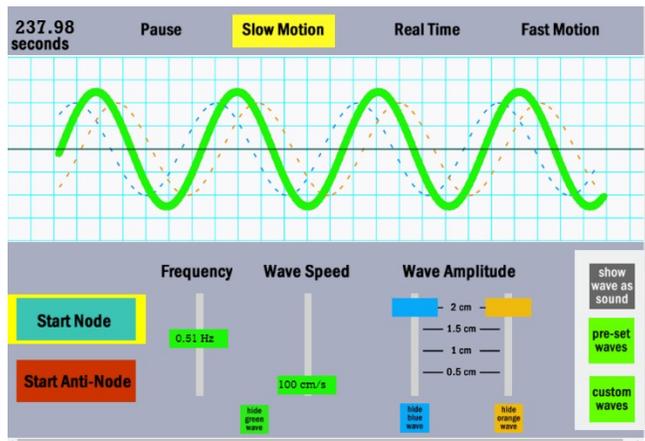
Purpose: The purpose of this activity is to design a musical instrument and predict the natural frequency. You will get to keep your instrument at the end of the activity.

Introduction: When you blow air into the instrument, you will start a standing wave pattern. Adding finger holes to the instrument will effectively shorten the length of the air column by creating a pressure node in the resonant pattern, producing a higher frequency (pitch) sound. While the mouth-end of the instrument that we are creating is not technically closed, the air that we blow into it creates a pressure node, similar to when the end of the slinky was held still in the Slinky Lab. The other end of the instrument is open, therefore it can either be a node or antinode, depending on the frequency of vibration. The fundamental frequency is the lowest frequency (longest wavelength) that the instrument can play and is referred to as the first harmonic. Closed-end instruments can only produce odd-numbered harmonics, so you will calculate the first, third, and fifth harmonic of your instrument in this activity.

Fun with a simulation:

Go to the Physics Classroom website and play with the Standing Wave Maker. <http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Standing-Wave-Patterns/Standing-Wave-Patterns-Interactive>.

Keep the simulation on “Start Node” because your instrument will have one closed end (mouthpiece) and one open end. View the simulation on “Slow Motion.”



1. What happens when you adjust the frequency? How does this compare to when you changed the frequency of the Slinky when making standing waves in lab?
2. Click on “Show wave as sound.” How do the crests and troughs compare to the compressions and rarefactions of sound (longitudinal) waves?
3. What happens to the air molecules in constructive and destructive interference for a sound wave?
4. Draw the first harmonic on the wave. How many antinodes are shown?

5. Click on “Next Harmonic” and draw the third harmonic of the wave. How many antinodes are shown?

6. Click on “Next Harmonic” again and draw the fifth harmonic of the wave. How many antinodes are shown?

7. What can you conclude about the harmonics and the number of antinodes in the standing wave?

Design your wind instrument:

**Download the MakerBot app <https://itunes.apple.com/us/app/makerbot/id881138579?mt=8>. Be creative with your design, consider adding folds to it and other features. Make sure your design has at least 3 finger holes, is hollow in the center, has a mouth opening, and an opening at the end. Your instrument cannot be larger than the maximum length produced by the 3D printer. Once your design is approved by the teacher, you may print it on our 3D printers. Do not forget to write your name on your instrument.



Teacher's Approval

Calculate the frequencies your instrument should play:

8. First, calculate the speed of sound in air, v and where T is the temperature of the room in degrees Celsius, using the formula. Show your work.

$$v = 331 \frac{m}{s} + 0.6 \frac{m}{s} \times T$$

$v =$ _____

9. Calculate the fundamental frequency of your instrument using the following equation, where the speed of sound in air and L is the length of the air column. The third harmonic is $3f$, and the fifth harmonic is $5f$. Show your work.

$$f_1 = \frac{v}{4L}$$

$f_1 =$ _____ $f_3 =$ _____ $f_5 =$ _____

10. Download n-Track Tuner (free) from the Apple Store with the link: <https://itunes.apple.com/us/app/n-track-tuner/id409786458?mt=8>



- Go to the needle view part of the app
- Play your instrument, finding all of the frequencies that it produces. Take a screenshot of the frequencies as they appear on the n-Track Tuner needle view and attach them at the end of this lab.
- Write the natural frequency (all the finger holes covered) in the box to the right and use this in the calculation below.

Natural frequency f_1 _____

11. Determine the percent error of the calculated natural frequency of your instrument to the actual natural frequency.

$$\%error = \left| \frac{\#experimental - \#theoretical}{\#theoretical} \right| \times 100$$

$\% error =$ _____

Screenshots:

Please paste your screenshots from n-Track Tuner here. Add as many pages as necessary.

What to turn in:

Please submit your Keynote presentation and this completed worksheet to the teacher through iTunesU for grading.

**Multicultural extension:**

Once you have turned in your project, partner with another early finisher and go to this website: <https://folkways.si.edu/ella-jenkins/jambo-and-other-call-and-response-songs-and-chants/childrens/music/album/smithsonian>. Each partner will choose a track and listen to the free sample, attempting to recreate the songs with their instruments.

Grading Rubric:

	0 Points	1 Point	2 Points	3 Points	4 Points ☺
Simulation Questions	Each question is worth one point for a total of 7 points, graded individually.				
Design & Construction	Did not produce an instrument	Missing 2+ features	Missing 1 feature or did not gain approval	3+ finger holes, hollow center, mouth opening, appropriate length, gained approval before printing, standard design, nothing unique	3+ finger holes, hollow center, mouth opening, appropriate length, gained approval before printing, unique design features
Calculations	No calculations were performed	Missing 2-3 calculations	Missing 1 calculation	Speed of sound, natural frequency, 3f, and 5f are correct. Work is not shown.	Speed of sound, natural frequency, 3f, and 5f are correct. Work is shown.
Natural Frequency	Missing information or no calculation was performed.		The % error calculation is incorrect	The natural frequency is listed from the n-Tuner app and the % error calculation is correct. Work is not shown.	The natural frequency is listed from the n-Tuner app and the % error calculation is correct. Work is shown.
Presentation	Did not submit a presentation	Missing three features. Submitted through iTunesU.	Missing two features. Submitted through iTunesU.	Missing one feature. Submitted through iTunesU.	Picture with a ruler, recordings of notes, frequencies are listed, and comments on design features are clearly shown. Submitted through iTunesU.
Evaluation & Reflection	Each question is worth one point for a total of 5 points, graded individually.				
Screen Clippings	No screen clippings are attached	1 screen clipping is attached of a frequency	2 screen clippings are attached of the frequencies	3 screen clippings are attached of the frequencies	4 screen clippings are attached of the frequencies
Extra Credit	2 points for whoever produces the most creative design, as voted by students in each class. In the event of a tie, teachers will decide.				