Build a Musical Instrument ~ *Project* Name: ________________

Inquiry Question
Ever wonder what it takes to create a musical instrument? Why do some instruments sound better than others? How can we tune them? Introduce yourself to the world of the crafting an instrument

Antonio Stradivari (1644 – 1737) created some of the most coveted violins on Earth. His remaining masterpieces have fetched millions of dollars at auctions around the globe. His techniques have been studied for centuries. What does it take to create beautiful sounding instruments? Can you create something that can be easily tuned? With a little patience and perseverance, you might be surprized.

Instructions
Using a pencil, answer the following questions. The lab is marked based on clarity of responses, completeness, neatness, and accuracy. Do your best! Please ensure that any data measured (or recorded) includes the appropriate number of significant digits (only one uncertain digit).
This activity is divided into three sections: • Core – this first section explores only the basic "core" ideas involved in understanding. Students must demonstrate a sound understand with all of their answers in this section BEFORE attempting the next section. • Mastery – Your instructor will NOT review this section if the Core section above shows any misconceptions. In this section students will make predictions and apply the concepts and ideas learned above. For complete mastery it is expected that data collection and scientific procedures will be as accurate as possible. All work shown should be clear with any units included. Answers should be rounded off to the correct number of significant figures based on the data collected. • Ace – Once again, your instructor will only look at this section provided he/she is confident that the above Mastery criteria has been met. In this section students will demonstrate a deeper understanding of the concepts through error analysis, experimental design etc. Physics concepts from other units already covered will often be required here.
This Project will be graded according to this Marking Rubric (link).

You are to create musical instrument that is capable of playing one full octave. **You are to demonstrate your instrument by playing a song that includes the notes from one full octave** (*do this either in **person** or by creating a **video***)

Objectives:

1. Construct a musical instrument out of junk and common materials such as plastic pipe, wood, glass, metal scrap, etc. Stringed instruments must have more than one string.
2. Demonstrate and explain physics concepts inherent in your instrument.

Rules:

- The instrument must be able to play an octave in tune.
- The instrument must be able to play a song. Songs such as "Mary had a Little Lamb" or "Twinkle Twinkle Little Star" are not adequate since they do not include all the notes in an octave.
- No *Kazoos*, Jaw Harps, Pop bottles filled with water, musical saws, washtub basses etc. When in doubt, ask.

Core Level:

Terms to consider and research:

Standing Waves, Nodes/Antinodes, amplitude, wavelength, frequency, interference

The "Core" instrument will play one full octave in the form of a song. You will complete the sections below that **document your progress** and test your basic understanding of standing waves.

Alternatively, you could create a video showing both the construction and completed instrument. Your video will include an explanation of the physics principles involved, in particular, you will clearly identify each of the terms listed above as they relate to your particular instrument. Use this guide as a "story board" to help ensure that your final video contains all of the necessary physics. Your notes will be in tune. **You** will be in the video. That way we will know it is truly yours!

What type of instrument are you attempting? ______________________

1. Basic Construction: Show the basic construction plans for your instrument below. Include all dimensions (even if they are rough at this stage) along with a list of materials required:

Materials List (describe in as much detail as necessary)
Construction and Design Drawings (include all necessary dimensions – your plans will likely require multiple drawings showing different viewpoints)

2. Take photos of your project to help explain the following terms (the physics):

<table>
<tr>
<td>Standing Waves: Photograph the part of your instrument that creates the standing wave responsible for the note produced). Paste in this cell.</td>
<td>Explanation:
Define Standing Wave (be sure to use "interference in your definition):
____
____
____
____

Draw a diagram showing the fundamental wave that would exist in your instrument. Your diagram should look like your picture (simplified of course). Label the Nodes and Antinodes directly onto your sketch.</td>
</tr>
<tr>
<td colspan="2">Based on your sketch above, describe how you would calculate the wavelength, λ, of your fundamental using the dimensions of the instrument pasted in the picture above. Show all work below and be sure to label any dimensions used to calculate λ directly onto your pictures above.

Fundamental wavelength λ_o = ____________ m</td>
</tr>
</table>

Determining Frequency, *f*: *Take s photo showing the method you used to determine the frequency of the note created by your instrument. Include any technology utilized.*	Using the frequency, f, and wavelength, λ, determine the speed, v, of the standing wave produced: *Show all work below and include units.* v = ____________ *m/s*

Mastery Level

Terms to consider and research:

Resonance and resonators, musical timbre, volume control, tuning ability, playability

The "Mastery" instrument will show a significant level of craftsmanship designed to amplify the sounds created and enhance the timbre of the instrument. This is often done with the addition of some sort of resonator (such as the hollow body on an acoustic guitar which is designed to enhance the vibrations created by the strings. You will have designed a way to **easily** adjust the tuning of your instrument.

You will complete the sections below that **document your progress** and test your basic understanding of resonator construction and function, timbre etc.

*A **resonator** is a device or system that exhibits resonance or resonant behavior, that is, it naturally oscillates at some frequencies, called its resonant frequencies, with greater amplitude than at others.*

*A **cavity resonator** is one in which waves exist in a hollow space inside the device. Acoustic cavity resonators, in which sound is produced by air vibrating in a cavity with one opening, are known as Helmholtz resonators.*

Wikipedia - https://en.wikipedia.org/wiki/Resonator

1. The function of a *cavity resonator* (or secondary resonator) is to enhance the frequency produced by the *primary resonator* (see Core above). To do this, it needs to be able to produce standing waves at either the fundamental frequency, or any of its harmonics. Determine the velocity of sound travelling through your secondary resonator by looking up the value for the speed of sound in that medium.
   Describe the medium (ie. If it is a hollow cavity, the medium is *air*) ____________________
   Speed of sound through the medium v = __________________ m/s

2. Determine the range of wavelengths that must resonator by calculating the longest and shortest wavelengths based on the lowest and highest frequency attainable by your instrument.

Longest Wavelength, λ *(based on your lowest frequency note) – refer to Core question (2)* λ_{long} = ____________
Shortest Wavelength, λ *(based on your highest frequency note)* λ_{short} = ____________

3. Take photos and insert them into the cells below to help document your progress and explain the physics involved.

Locate the secondary resonator (cavity resonator if you constructed one): Take a picture of this component and paste into space below:
Sketch how the standing waves generated in the resonator might look on a simplified diagram
Does your secondary resonator design enhance a number of frequencies? Explain, with the assistance of a labelled diagram, how your instrument enhances both the upper and lower frequencies. Mathematically show how the dimensions match the wavelengths (by the standing waves they generate) produced by your instrument (or the higher "harmonics")

Part 3: Ace

Terms to consider and research:

musical timbre, tuning ability, playability

The "Ace" instrument will be truly amazing. Your instrument will resonate beautifully for all the notes. Anybody would be able to play it. The individual notes can be "shaped" while playing (bending notes, vibrato etc).

For an "Ace" instrument you will have made extensive use of technology to help improve the quality of the sound. Your resonator will show a complex timbre when notes are played and add to the richness of the sound (looking at an FFT or Fast Fourier Transform graph while playing can assist with this).

You will have developed a scientific procedure to track any changes and modifications made (is the sound louder, has the "timbre" improved)? Is the note better quality in terms of pitch? You will have utilized a variety of software to help hone your sound. Your video will include an explanation of the physics principles involved, in particular, you will clearly identify each of the terms listed above (both in *Core* and *Mastery*) as they relate to your particular instrument. Your video will also clearly show the "before" and "after" effects to the sound or function of the instrument with each modification (good or bad).

Software and tables (suggestions) for Project 1 above.

- Table of Frequencies: Here's a table of note frequencies. It also includes wavelengths calculated for v = 345 m/s
- Audacity: Free, open source sound editing program (windows, mac, linux). We'll use it for determining frequency of notes played. Simply record your note. Highlight your sound in the track and select "Plot Spectrum" from the "Analyze" menu. This will do a FFT (see picture).
- N-Track Tuner: Simple. Works well will Ipad and android devices. You'll have to figure out a way to screen capture but the frequency graph it generates is of good quality
- Visual Analyser: Free oscilloscope program for Windows. This one is a must for Windows users. It also includes real time FFT.
- The Physics of Musical Instruments by David Lapp: This is a must read. It is a free textbook written to teach sound and music. It covers the different instrument types and goes into way more detail than your students would need to finish their projects.

1. Research: What is meant by the *timbre* of a musical instrument? Discuss how the *timbre* quality defines the musical instrument. In your own words please!

Timbre (as it relates to standing waves, interference, and harmonics)
____
____
____
____
____

2. Using software of your choice create an FFT (see above for software suggestions) by recording your "best" note. Take a snapshot of the graph and paste it into the window below.

FFT of best note: *Paste FFT created below*
• Label directly on your FFT the fundamental frequency that defines the note. Determine the frequency of this note by reading it directly off of the graph. Label it f_0 and include the value of the frequency. • Locate all of the other harmonics present and label them f_2, f_3, etc. Be sure to determine the values of each frequency as well.

3. Disengage your secondary resonator by either removing it or damping it out (stuff the cavity with a rag for example). Create another FFT for the same note as above and label as above:

FFT of best note: with resonator disengaged

4. Compare your two FFTs above. Justify, using the results of the two graphs above, that the timbre of your instrument has improved with the addition or your resonator.

____

____

____

____

____