HU 3910 E-2 2024 HUA Report

String Afterlength

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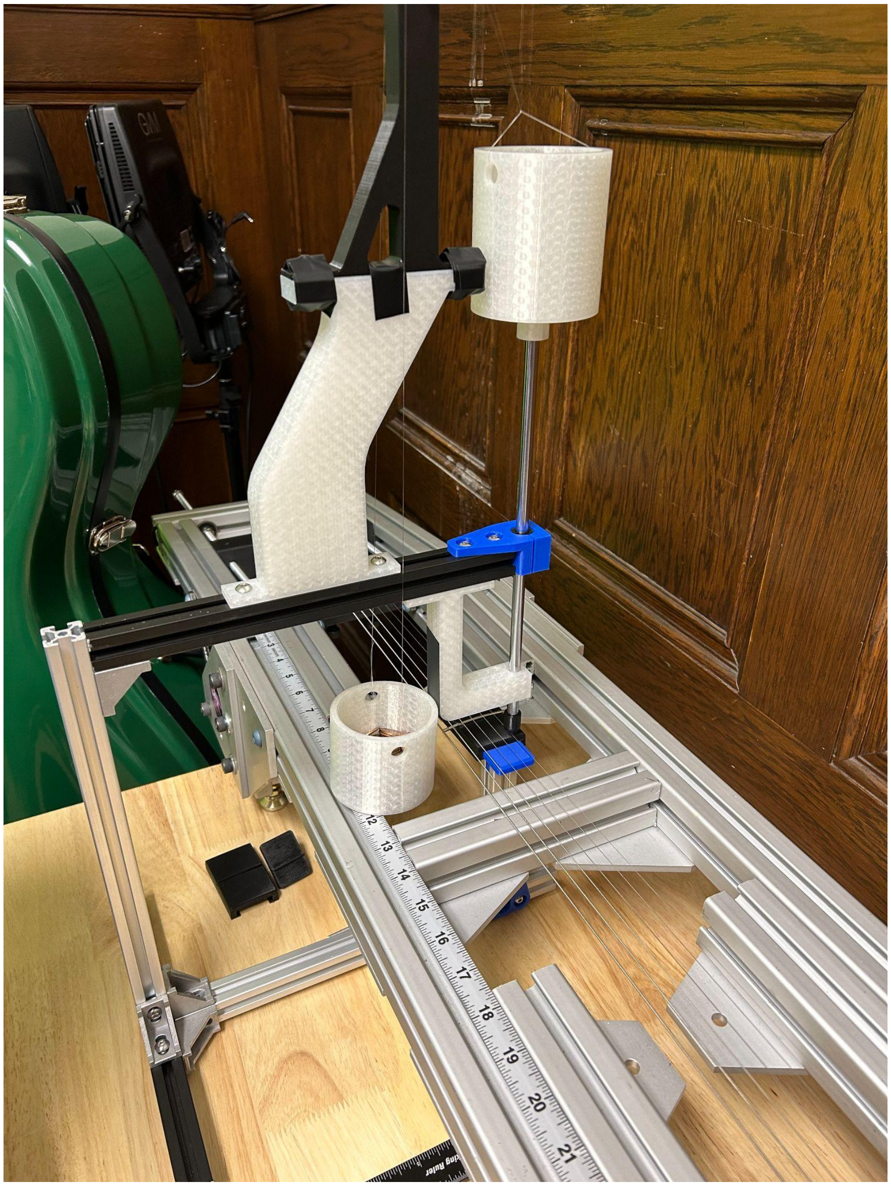
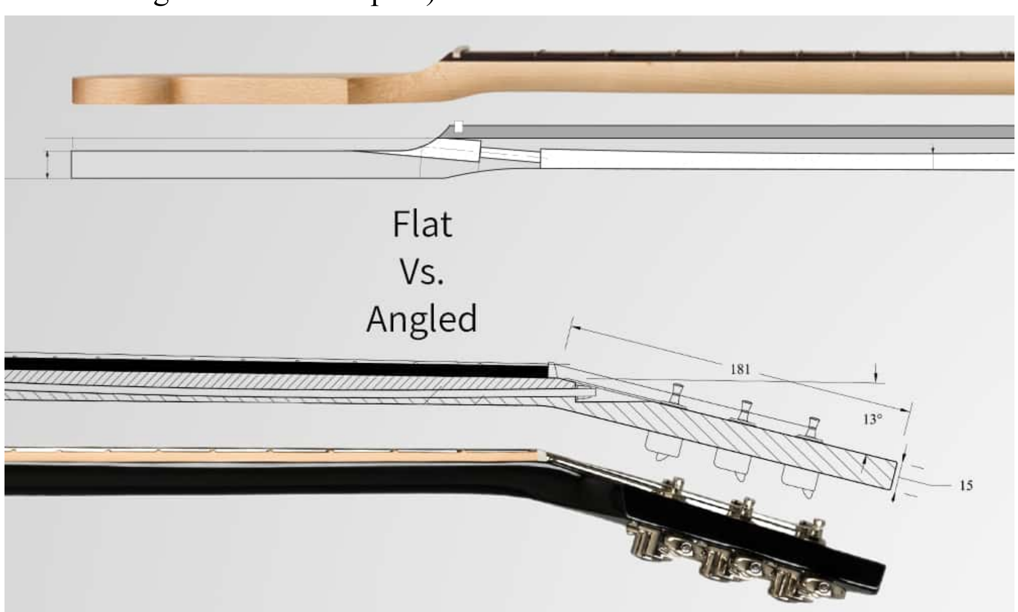


Background:

Headstock

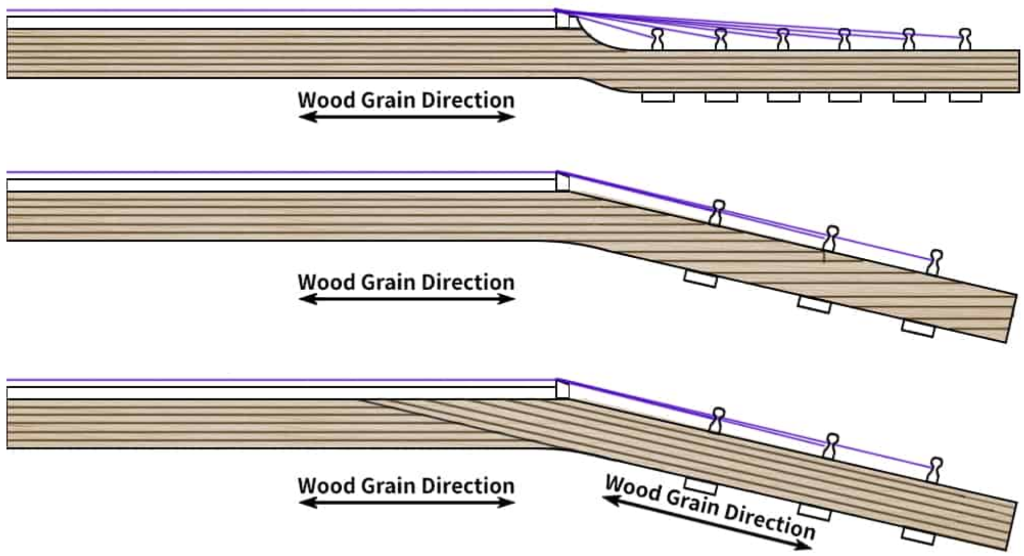
The headstock of a guitar is the area on the guitar's neck that holds the tuning pegs and end of the strings. This is necessary for the tuning and sounds that the guitar makes and come in a variety of shapes, sizes, and angles. These variations are important in how the guitar looks, functions, sounds, and feels to the player. For example, it is important that each nut slot is parallel and perpendicular to other nut slots on the headstock to keep it sounding good and making it tunable. There are many different variations of headstocks which change the feel and tuning stability of the instrument. For example, in a Gibson Les Paul design (3 tuners on each side), the pegs are closer to the nut making it more stable than a 6 in one design like the Fender Strat (Heather).

Another important part to consider about a headstock is its angle. Different guitars have different angles mainly due to aesthetics and player preference. Having an angle is important for putting pressure on the nut, creating a break angle, and keeping the string in place all which helps the intonation of the guitar. Guitars are made at all different angles-going all the way from 5-25 degrees, most commonly staying at around 11 (“The Science of Guitar Headstock Ergonomics - Seeking the Perfect Shape!”).



The headstock angle affects the break angle, so if a guitar is too shallow of an angle then the string might slip, but if it is too drastic of an angle for a headstock it may add too much pressure and affect the tuning.

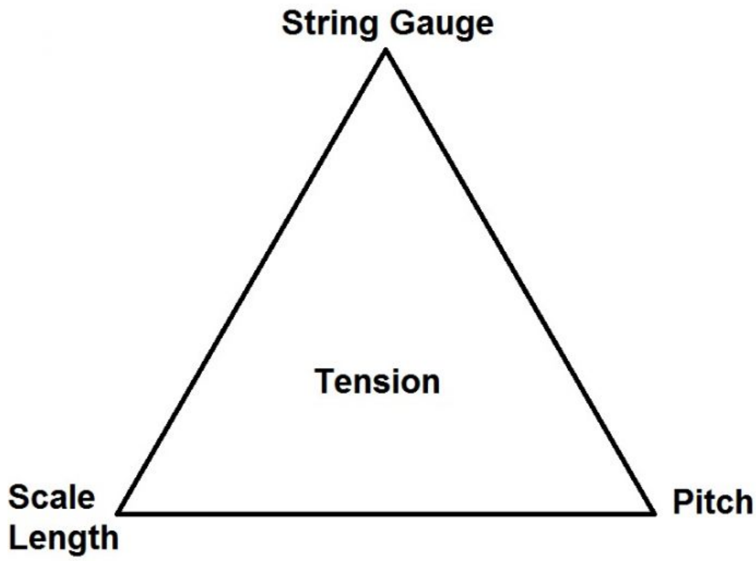
Another component to consider is strength. Flat Headstocks are typically stronger because the wood grain direction shifts less with a smaller angle.



Overall, headstocks exist and are used with a variety of angles. Each company and guitarist has a preference but both are functional (*Angled vs. Flat Headstock, Which to Build? - Electric Guitar Lutherie, DIY, Repair and Maintenance*).

String Tension

String tension is a very important aspect of playing a guitar. This measures (in pounds) how tight the strings are. The string tension is another part of the guitar that is variable due to the type you buy and also the player's preference: some people like the strings to be more stiff and others more loose. The three components that go into string tension are string gauge (measure of string's thickness) , pitch (note it is tuned too), and scale length (length of vibrating string). Thicker/ heavier strings increase tension to a pitch more than a thinner/ lighter string going to the same pitch. Strings being wound also increases the string tension in the Guitar. Each note on guitar has a different tension and therefore different amount of force required to hold the string down ("What Is Guitar String Tension? | D'Addario Lesson Room").



Fretboards

The fretboard of a guitar is the part on top of the neck that controls where the frets are placed. This is used to hold the guitar string down against the frets. This is important because the vibration against the frets is what causes the notes. The closer you play to the body of the guitar the higher the pitch, and the closer to the nuts the lower the pitch is played. Most guitars have over 20 frets of varying length to make the correct notes.

Project

For our HUA, we are continuing work on the String Afterlength Project, which focuses on the effect stockhead angle has on force needed to hold down the string. This is important to see how this affects the player's experience and overall force to move down a string depending on the angle. When we started this project there was already an established setup and CAD files which made jumping in very easy. The previous groups gave great information to make it simple to learn about the setup, strengths, and weaknesses of the project. This also gave us a great jumping off point on what problems to fix first. Our job was to make this setup more reliable and lifelike this summer. This fell along the lines of three areas of improvement. The first of which to eliminate the metal-on-metal sound caused between the metal rod on the string, providing a more realistic sound. This also caused the string to slip from the rod, therefore stronger contact between the rod and string is needed. The next being to incorporate a more realistic fretboard, and subsequently sound quality, while making it possible to test the optimal fret-finger placement. And last was to improve upon the counterbalance system, with the goal to put the system in equilibrium in order to test specific tensions on the string more easily.

Brainstorming

We started this project by getting familiar with the setup and deciding what problems to solve. We decided that we wanted to focus on improving the mock fretboard and attaching something to the end of the metal rod to make the simulation more realistic of a person holding down on the fret. We also thought about ways to fix the counterweight and issues with friction. Some ideas we came up with were:

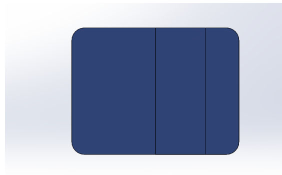
- Fret board
    - Adding a divot to add a piece of a real, usable fret
    - Making an addition of an actual fret on the 3D Printed model
    - Make multiple versions to test different sizes and lengths or make it adjustable
- Rod Attachment
    - 3D printing a way to attach the piece vs. gluing it on
    - Thinking of materials for the piece to best simulate a person while gripping the string
        - 3D printed part, the soft end of a stylus, finger guard for correct shape
- Counterweight
    - Measure the rod and get a more precise measurement of the weight to purchase a counterweight that is precise and easier to use than a lot of weights.
    - Use a shorter string to reduce collision with the jig.
    - Use a sensor instead of coins to be more precise.
- Reduce Friction
    - Make 3D printed parts metal
    - Find a more slippery string
    - Restring to get a larger angle to prevent collision and reduce friction

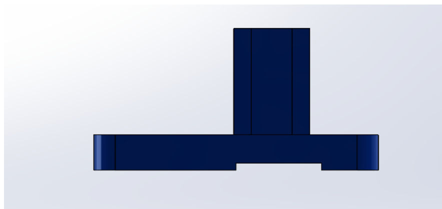
Drafting and Designing

<u>Fretboard Attachment Design:</u>

The most in-depth part of this project was the designing and drafting. Although it may look like a few small changes were made, what was not seen was how many models and versions were made and tested. We made a variety of each part we designed and tested each of those to see which worked the best and was most realistic. We also had to keep tweaking dimensions and sizes of parts to make sure we came up with the best end results. Here are pictures from a few of our designs.

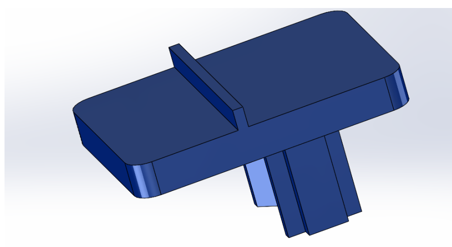
First Design of Fretboard Attachment:





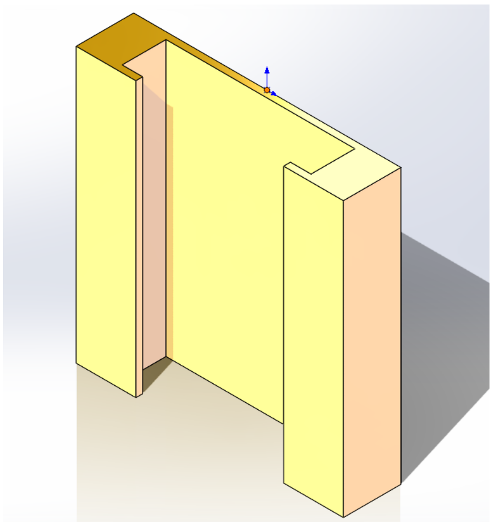
In this design we created a sunken-in section of the mock fret. This would allow us to slide a small piece of a fretboard into the 3D printed part. This is good because it would be a realistic and used fret and also could be interchangeable with different variations and distances of frets because they were able to slide in and out. The main problem with this is it would require you to cut up a fret board which was not very convenient and would also have to be customized to a specific fretboard. Any variation in wood thickness would need the sunken section to be redesigned and reprinted. Ultimately while this was a good thought, it was not very practical.

Second Design of Fretboard Attachment:



The second design was much more successful. We added a 3D printed fret to the model and printed it in one piece. This reduces the clutter and potential for pieces being lost. After testing it on the model we noticed that it helped with sound quality a lot! It was a little too tall, but ultimately an improvement in being more accurate and in a good placement. After testing it, we wanted to see different fret distances, but thought having that much variety would be inconvenient to print and store, so we redesigned it to be adjustable.

Sliding Fretboard Attachment Design: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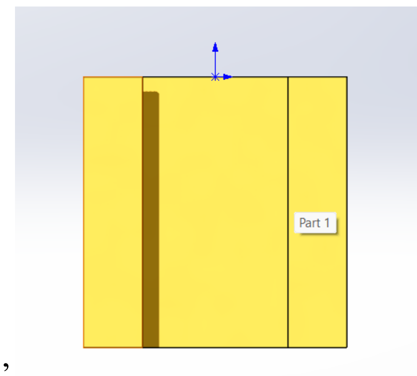
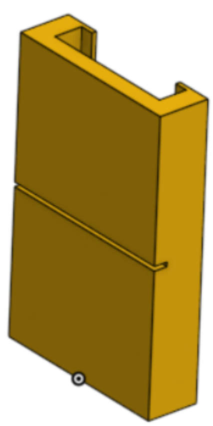
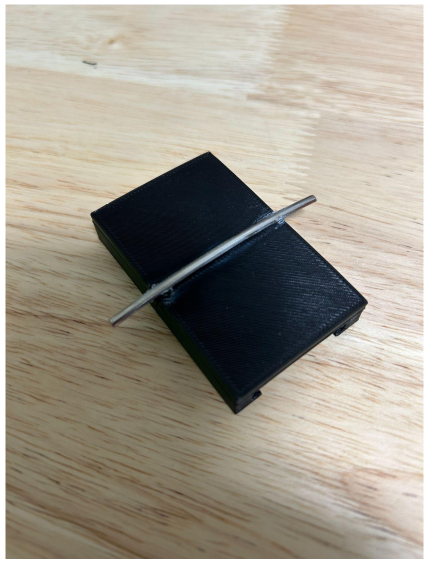
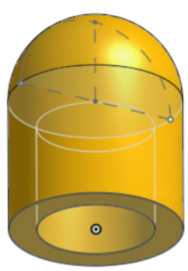




This is the final concept that we went with and implemented in the jig. This is a piece that goes over the originally designed fretboard and can slide around. This makes the fretboard able to move back and forth and lets users test for the optimal fret-finger distance. Upon testing the effectiveness of the slider, we then revisited attaching a fret to this design. We purchased frets and designed a grove in the slider piece to attach the fret. We designed it so the fret was placed at the max distance between two frets on an actual fretboard from the end of the slider. We based our measurements off of a detached fretboard in the lab, where the largest distance between two frets on the board was found to be approximated 1-½ inches. Below is the final product for the fretboard slider with the fret attached.



Rod Attachment Design:



We ended up designing a 3D printed component roughly the same size as a finger and a way to attach it to the steel rod. The plastic “finger” was made with an insert the same diameter of the metal rod. Upon attaching it, we found that it was too loose, therefore we applied a layer of double sided tape around the end of the metal rod and simply slid and attached the plastic “finger” to it. We steered away from gluing anything to the rod in case future groups wish to redesign our idea instead of having to work around it. We then decided to glue a stylus tip on the end of the plastic “finger” to simulate a finger due to its soft and skin-like texture.

Counterbalance System Design/Theory:

The final and most challenging area of focus was trying to fix the counterbalance system. One side of the counterbalance system contains the metal rod in which applies tension to the string when weight is added to that side. Weight can be added to the metal rod side with a cup attached to the top of the rod. On the other side of the counterbalance system, there is another cup. These are attached to each other via a pulley between the two sides of the counterbalance system.

The problem we had to deal with was achieving equilibrium in the counterbalance system. Before we began, the counterbalance system was too heavy on the metal rod side. This made it so it was harder to tell how much force is actually being applied to the string since the rod itself was already applying an initial force. To achieve equilibrium, we first took the mass of the metal rod side of the system, which we found to be 165.828g. Next, we would have to balance the torques on the pulley itself. This was initially unbalanced due to the difference in mass along with differing angles. To make matters easy, we proposed making the angles of the strings from the pulley in respect to the y-axis of the system equal. This would allow for an equal amount of mass, 165.828g to be exact, to be applied to the other side of the system, ultimately achieving equilibrium. Once this occurs, weight can be applied to the rod side of the system, where said weight that was added would be tension applied to the string.

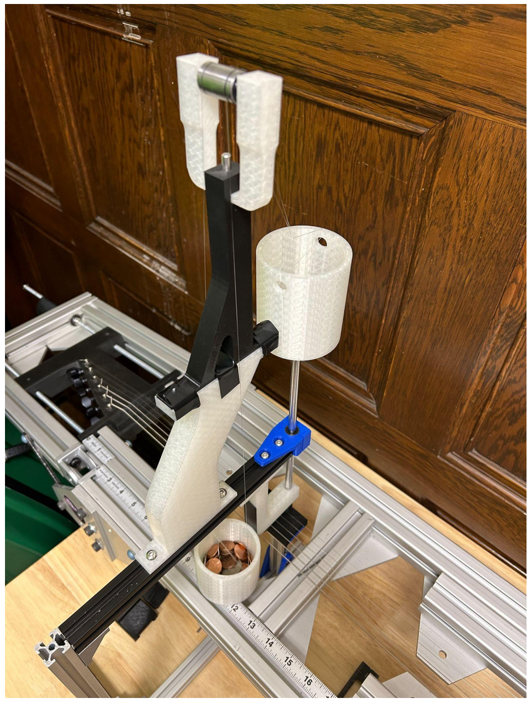
However, this requires a system with minimal friction, where unfortunately our system had plenty of it. We determined numerous spots in which friction occurred: two between the rod and plastic where the structure guides the rod perpendicular to the fretboard, and between the cup on the rodless side as it rubs against the structure. There was also a problem with this cup getting blocked by the structure when it descended. This could be solved if the angle of the string holding said cup between the pulley was increased.

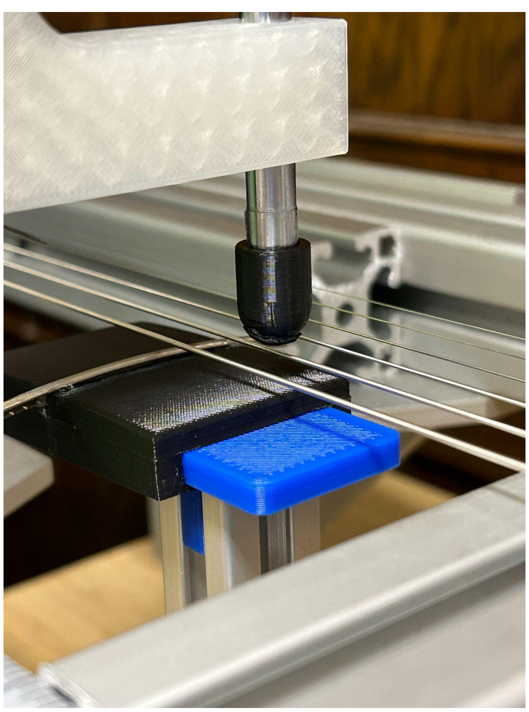
We also proposed adding a force sensor to the rodless side of the system which would measure the tension of the string on said side. This could be set up so the angles of the pulley strings are equal, leaving simple physics to determine the tension on the string.

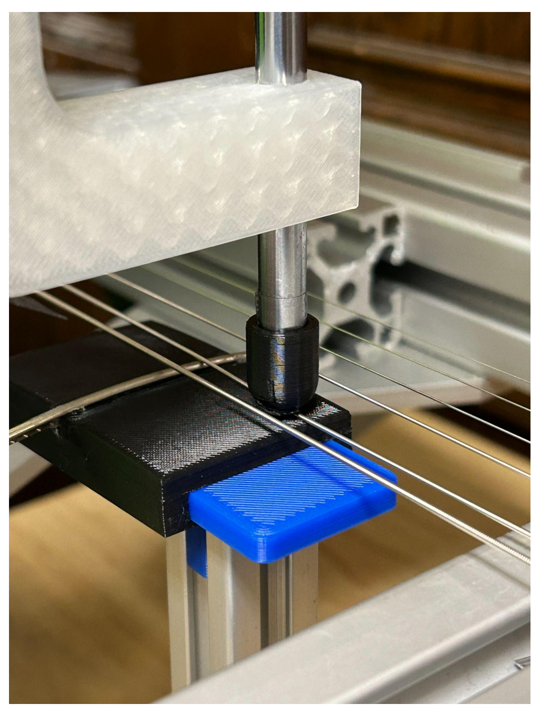
Implementation/ Results

With a little bit of trial and error, we got a lot of this to work. The rod and fretboard attachment resulted in a more clear, clean, and realistic sound, together ending the metal-on-metal noise and helping to improve the sound quality. The slider also perfectly allowed for the fretboard to move, allowing for future measurements on the optimal fret-finger position to be made.

As for the counterbalance system, we tried putting the system in equilibrium using coins, where we measured out the appropriate amount of coins to balance the system, however even with equal amounts of mass on both sides and equivalent string-pulley angles, it was incredibly hard to balance.







We concluded this was due to excessive friction in the system. We tried oiling the rod so it wouldn't rub up against the structure as much, however achieving equilibrium was still harder than anticipated. In the amount of time we had, we couldn't continue design and testing on the counterbalance system, therefore we can only leave suggestions on what needs to be done. Overall, we solved many of the functional issues and helped make the rig more realistic and effective.

What We Would Do Next

We discovered a lot during our time on this project. Some of the biggest challenges we faced were not working together in person. One member was not able to come on site and see the project in person. This made us rely heavily on communication and teamwork. Overall, we feel proud of the work we have done to move this project forwards but also recognize that there is more work to be done in the future. We would recommend adding a sensor to the counterweight to make more precise and accurate tension measurements along with testing our recommendations on how to achieve equilibrium in the system. For improvements on the rod attachment, we recommend making more options. By adjusting the rod attachment, you could make smaller and larger "fingers" and also try different materials on the end. This would be beneficial to simulate different people's fingers and to see what material is most human like to continue to improve testability, accuracy, and sound quality. In other words, explore more questions on what affects the quality of sound on a guitar. We would also recommend using the Washburn Machine Shop to convert many of the 3D printer parts to metal and get a lighter metal rod to help reduce friction.

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