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Energy Creation via Seesaw Up and Down

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Seesaw: Energy Generation from Up and Down Motion

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Abstract

We are striving to find renewable energy sources, either by improving current designs or by harnessing wasted energy. As today's world becomes increasingly aware of the advantages of reusable energy, it is becoming very beneficial to look for sources of wasted energy in everyday life. When people play in parks, the energy that they apply to the equipment in the park goes to "waste." The energy output during their play often works to create a torque on some piece of equipment, which then translates into rotational kinetic energy, which is then transferred to heat energy through frictional forces. By "waste," we mean that this rotational kinetic energy is not harnessed into a form of energy that we could use later; instead, being converted to thermal energy, which is lost to the surrounding space. We could use this potential source of unused energy to power much-needed electrical devices, such as lighting, which can help increase safety and comfort in and around the park.

To solve this problem, we need to design a way to convert the rotational kinetic energy applied to the park equipment into a usable form of energy. While there is a wide array of possible equipment that we could use to harness this energy, we focused on the seesaw. While moving up and down, we think that our seesaw could produce a sustainable energy source to help reduce electricity needs in parks. We hope that this prototype can play a role in the real world or lay the foundation for the next generation of energy innovation.

Introduction

The world has been rushing to design and develop new ways to harness energy over the past couple of decades. Most of our energy is generated from fossil fuels in our current society. This method has its pros and cons. The pros are that they are relatively easy to transport, and the amount transferred has a large energy density. The cons are a limited supply of materials we can use, national security issues regarding OPEC's significant role in producing the world's oil supply, and health and environmental issues. In recent years, professionals have concluded that the cons outweigh the pros and that we need to find a better alternative than fossil fuels. That would be renewable energy [1].

Part of the energy we use every day is generated through solar, thermal, and wind-powered energy. These sources have dominated the renewable energy fields, but another way to produce energy cleanly has been ignored. Every day humans release energy while completing day-to-day tasks. All of this energy essentially goes to waste if it is not harnessed. Scientists have realized this and started to capture this energy in various ways like generators powered by revolving doors, footsteps making electricity, and foldable energy packs [2]. We thought of situations where this type of kinetic energy was lost as a team. We realized that a significant amount is wasted at playgrounds in our brainstorming.

People of all backgrounds, ages, and sizes go to playgrounds and happily use the equipment there. Whether it be the merry-go-round, a swing set, or a slide, all the energy the user inputs into the activity is lost. We conceptualized ways to harness this energy using playground equipment [3] to have a "Self-Sustainable Energy Park." We can efficiently produce energy this way from the hybrid generator/playground equipment devices. We could help solve the rising energy dilemma while making parks or playgrounds safer and more convenient. By powering streetlights and security cameras, placing down and powering more drinking fountains, charging stations, and if we generate enough, maybe even the surrounding housing area. However, with constraints like costs and time, we opted to build one of the devices as a proof of concept. There were several playground equipment's that we could have used for our proof of concepts, such as merry-go-rounds or swings. We found the easiest and most efficient thing we could siphon energy off is the seesaw.

An energy harnessing seesaw would capture part of the rotational kinetic energy made during play and convert that into electrical energy, thus using all that kinetic energy generated and consumed into the thermal energy of the surroundings and putting it to good use. Seesaws are generally constructed of a beam balanced on a base to be ridden up and down for pleasure, with seats and handles for safety. When converting the energy types, we used a hand-car system to fully utilize the two directions of rotation that occur when oscillating on the seesaw. The seesaw moves the connecting rod, turning the crank attached to the big gear (crown wheel), which is meshed to a smaller gear (pinion wheel) with a gear ratio of 5:1 that then turns the motor shaft using electromagnetic induction to generate electrical energy. We used the reverse process of how an electric motor is turned to generate electricity.

We used our seesaw to spin the tightly coiled wire manually within the permanent magnetic field. Electromagnetic induction creates the electromagnetic field produced by the flow of electricity, essentially forcing an electrical current. The generator would not interfere with the seesaw experience, and the energy created would be transferred from the generator into a battery pack or directly into a light source. We would also need to make it to store it easily or find a place to keep it.

Methods and Approach

We began by brainstorming ideas of how humans produce mechanical energy that is not captured by any device or converted into electricity. We landed on two activities during which people frequently do this, using equipment in the gym, such as stationary bicycles and weight machines, and playground equipment in parks, such as seesaws and merry-go-rounds. We then decided that we would better suit playground equipment to our project, as we would be more easily able to construct a custom apparatus that we could use to generate electricity [4]. We also found in our research that capturing energy in a gym setting was already a popular idea that had several designs online. We were more interested in creating a more innovative creation that may inspire more work in a new setting [5].

Now that we had a general idea of how our project should work, we designed and constructed the prototype. We made a small seesaw made out of a pinewood base, cardboard sides, and a wooden dowel that had a diameter of one-eighth of an inch. We attached two SparkFun wheels glued together on one end of the wooden dowel so the rims faced each other (See Figure 1). This allowed us to insert the inner wheel's hub onto the dowel and the outer wheel's hub into the SparkFun motor. We then connected a multimeter to the SparkFun motor to get the voltage and amperage outputs (See Figure 2).

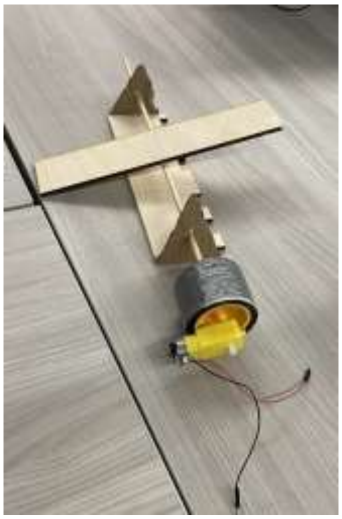

Figure 1: Seesaw Prototype

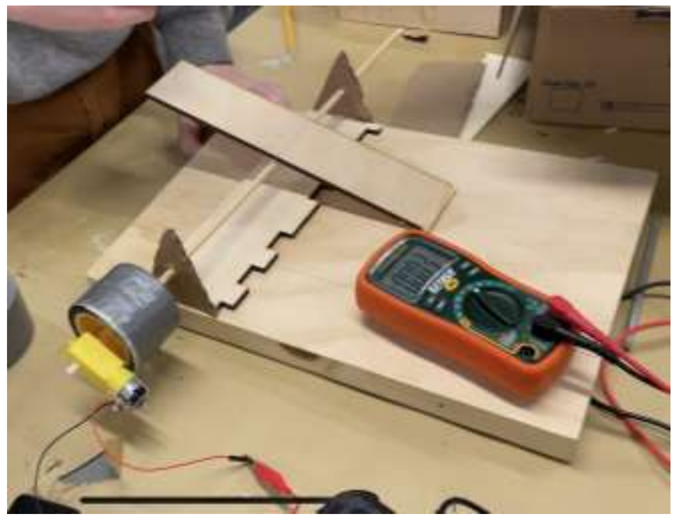

Figure 2: Prototype attached to multimeter

	Average	High	Low	Median	Standard Deviation
Voltage(V)	0.625	1.088	0.120	0.650	0.267
Amperage (mA)	18.82	OL	0.27	10.71	22.29

Figure 3: Voltage and Amperes Outputted by Prototype

Our data proved that it was possible to generate energy from the rotational energycaptured from a seesaw device (See Figure 3). The data we collected allowed us to make the conclusion that if our average voltage generated from our pint size project was 0.625 volts, that final project would be able to make a greater amount of usable energy. Satisfied with our results from our prototype and its outputs, we moved on to making the final design

We began our final design process by first creating a blueprint for our seesaw using the 3D modeling program Solidworks. This would essentially provide the infrastructure for how we would generate electricity. Our primary design consisted of three major parts. We would create a structural base, a central beam structure, and an axle to connect the two. We decided to make the base a rectangular shape that we would place on the ground to provide stability and keep the seesaw from tipping over while being ridden. The beam structure, which would be the actual structure that people ride on and push up and down, was a relatively simple rectangle with a long length and small width to fit between the legs of rides. The axle was perhaps the simplest part as it was just a rod that would be placed through horizontal holes in the beam structure and would be supported by vertical pieces extending from the base structure. Once we had completed our design, we realized that it was very long and its unwieldy structure would make it difficult to transport as it may not fit around corners in our university halls, making transportation and storage nearly impossible.

To counter this, we decided to cut the beamstructure into three shorter pieces that would be connected by hinges so that the longer pieces could be folded up into the middle, allowing for our longest dimension to be effectively cut in half. We decided that with this adjustment, our design of the initial structure of the seesaw was complete. With this done, we moved onto deciding what materials we would use. We concluded that we would use 2”x4” pieces of wood for everything other than the axle. For the axle, we useda wooden curtain rod with a 1⅜” diameter. We cut our pieces of wood to their desired lengths according to our blueprint and constructed our seesaw using screws to connect necessary pieces to each other.

Next, we began to design our system that would convert our up and down oscillating rotational motion into electrical energy. We first decided that we would try to convert the oscillating rotational motion into one-directional rotational motion. We believed that this would make it much easier to connect to the device we would use to create electrical energy, as the rotational motion would keep its momentum instead of changing direction every time one side ofthe seesaw changed direction. We researched ways that we could accomplish this and decided that we could incorporate a handcar system into our design. This system works by having a rotating “driver” object that is attached to a rod about a certain radius and changing the direction of rotation before a full revolution is achieved. The other end of the rod then rotates around a smaller radius. This smaller radius allows the end of the rod to complete a full revolution while the end attached to the driving rotation only completes a portion of a revolution. We found that this would be an ideal system to use in our design as this could convert the changing direction of rotation of the axle that comes from the seesaw going up and down into one directional rotation.

The next step in our design process was to connect this rotational motion to the electricity generating device. We decided to use a gear ratio to increase the speed of rotation that would be driving the generation process, as we planned on using electromagnetic induction to generate electricity, which outputs more electricity with a higher rotational speed. This was possible for our design because we had a large torque being created by the two people who would be using the seesaw, but a low rotational speed, as they would only go up and down once every second or two. Using a gear ratio would allow us to convert our high torque into higher rotational speed. Using a large gear with a high number of teeth would allow us to spin a smaller gear with fewer teeth at a faster rate.

Design Details

Our final design can be separated into two main aspects: the seesaw itself and the system that translates its back and forth motion into circular motion (also known as the handcar system).For the seesaw, we thought it would be best to use wood for construction. Wood is inexpensive, easy to use, and is strong enough to withstand any forces that would be acting on the seesaw. All of the pieces of wood used to create the seesaw were cut from 4 foot long 2”x4” wood planks. The middle beam that moves back and forth was constructed by connecting two 4' long pieces with a 6" piece on either end (See Figure 4). The base was then constructed by connecting two vertical 2' pieces at the bottom with two 1' pieces. Another two 2' long pieces were added perpendicularly to the 1' pieces on each side to provide support to the base (See Figure 5). With the base and beam complete, they were connected using a 1.25" wooden dowel. Holes were drilled through the top of each vertical support on the base and through the middle of our center beam so that the dowel could be passed through (See Figure 6).

Figure 4: Completed Beam

Figure 5: Completed Base

Figure 6: Completed Base and Beam

We again used Solidworks to design the handcar system and the gears to be used in the gear ratio. For these systems, there were six parts that we designed in Solidworks. We first created a circular piece that would fit around the central seesaw axle (See Figure 7). This axle piece had a ¼" hole for a rod to fit into, set at a radius of 1". This would act as the part of the handcar system that drives the rotation and does not make full rotations around its axis. The next piece was the connector rod for the handcar system (See Figure 8). This was a ¼" diameter cylindrical rod that would be able to easily fit into the holes of the axle and drive connector parts.The connector rod was bent at a 90° angle in two places so that the rod would be able to slideinto the two pieces to which it was connected. The third piece was the last part of the handcar system (See Figure 9).

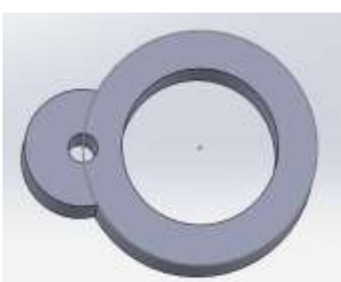

Figure 7: Axle Connector

Figure 8: Connector Rod

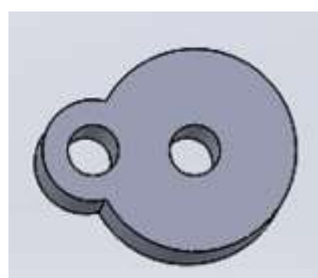

Figure 9: Drive Connector

Similar to the axle part, it was circular and had a ¼" hole for the connector rod to fit into. This hole was located at a radius of 0.375" in the axle part so that the handcar system would be able to function and generate a single directional rotation. It also had a ¼" hole through its center so that we could attach another axle to it. This axle would be what connects to the gears and drives their rotation. We then planned the gears, which were relatively simple to design. The larger gear had the a 1" diameter hole in its center with two rectangular holes extending from the center hole (See Figure 10). The smaller gear needed to have fewer teeth than the large gear (See Figure 11). The hole in the middle of it also needed to match the drive shaft of the motor as the smaller gear would be what connects to and causes the motor's drive shaft to spin [6].

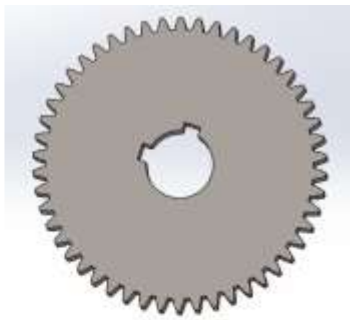

Figure 10: 50 Tooth Gear

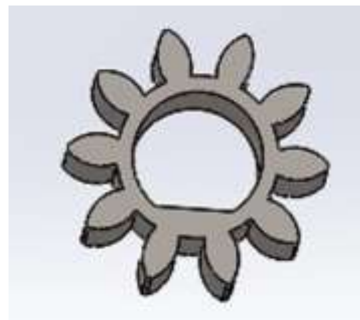

Figure 11: 10 Tooth Gear

The last part that was needed was the piece which would connect the drive connector and the large gear. (See Figure 12) This piece was cylindrical with a 1" diameter. We designed rectangular extensions at two points on the part so that the piece would be able to fit into thelarge gear and have a point at which it could exert torque onto the gear. It also had a ¼" cylindrical piece that extended outwards from the face of the part which would allow it to connect to the drive connector part.

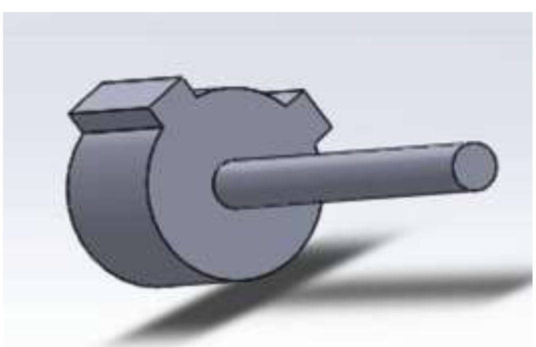

Figure 12: Gear Drive Connector

Figure 13: Complete 3D Design of Handcarand Gear System

When the designs were finished, each of these parts was 3D printed and the system was assembled on the seesaw. (See Figures 13, 14, and 15) The axle connector was glued to the axle of the seesaw, which allowed us to measure out the correct location to place the drive connector for the handcar system to function. A hole was drilled through the wooden support so that the gear drive connector could pass through and connect the handcar system on the outside to the gear ratio on the inside. A final two 1' pieces of wood were cut to support the motor in between the vertical supports. A whole was drilled in the support so that the motor drive shaft with the 10 tooth gear attached to it could fit between the supports. With these steps taken, our energy generating system was complete.

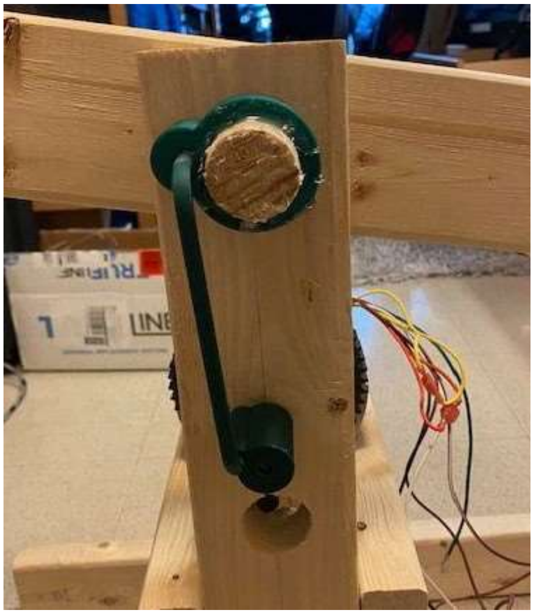

Figure 14: Complete Assembled Handcar System (Outside View)

Figure 15: Complete Assembled Handcarand Gear and Gear System (Inside View)

Results and Discussions

With our final design completely assembled, we were able to hook up our motor to an Arduino board where we recorded the output voltage of our system fully functioning. The Arduino code outputted the data we were collecting onto a serial plotter which we used to easily visualize the results. The results were not as impressive as we were hoping, with an average output voltageof around 30mV and a max output voltage of around 60mV. (See Figure 16) This was disappointing for obvious reasons and led us to delve more deeply into the science behind electromagnetic induction and motors to try to figure out why this did not work as we suspected.

The problem laid right there in the verbiage of our question, motor. We had purchased and used a motor, which is designed to have a voltage input and translate that into a rotary output, not the other way around. Due to the laws of electromagnetic induction, and as evident in our data collection, this does work a motor can and will generate electricity if you input rotational energy. However, it is not optimized to do this that would make our motor a generator, which would have been an ideal option for us to purchase and use. The ideal purchase and application would have been that of a DC generator [7]. Thankfully, there is a way to calculate, using the input rpms that we generated, the voltagethe generator is rated for, and the frequency the generator is rated for, to calculate the theoretical output voltage of our ideal proposed system.

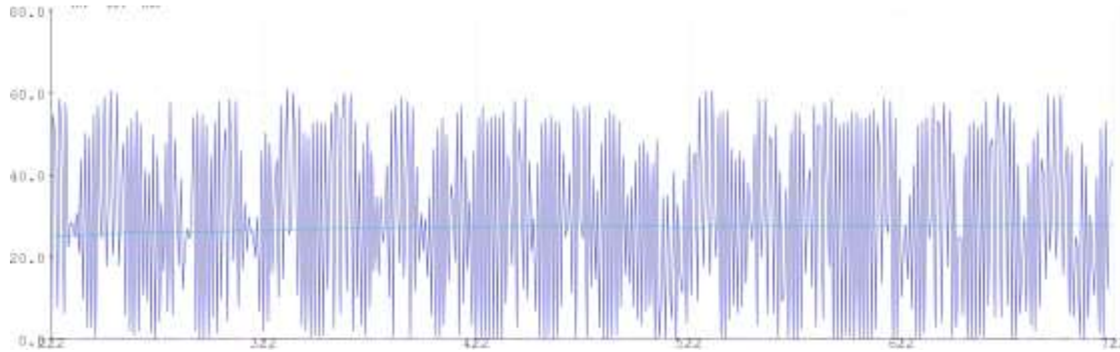

Figure 16: Output Voltage over Time Graph

To do these calculations we created a code in Matlab where we can input these variables and it will return the theoretical voltage. (See figure17) For the values of the generator's rated voltage and frequency, we simply used the values of the motor we purchased for simplicity's sake, but in buying a generator, it is likely these values would vary, and would have to be changed accordingly to more accurately predict the output voltage. Keep in mind these results are assuming a 100% efficiency, which is impossible, so actual results from this proposed system would be lower, based on the generator's actual efficiency. Based on reference [8], mechanical to electrical power efficiency is less than 10%.

Voltage_Forecast.m

```
RHz = input('Enter Rated Frequency of motor: ');
RV = input ('Enter Rated Voltage of motor: ');
Rpm = input('Enter Drive Shaft Rpm: ');

Hz = Rpm/60;
Ratio = Hz/RHz;
OV = (Ratio*RV)

```

Command Window

```
>> Voltage_Forecast
Enter Rated Frequency of motor: 60
Enter Rated Voltage of motor: 219
Enter Drive Shaft Rpm: 160

OV =

    9.7333
```

Figure 17: *Equation from the Founder of Embed inc. Olin Lathrop* [7].

A forecasted 9.73V fares far better and shows much more promise for our idea of electricity generation. While, as mentioned before, we are disappointed with the actual results of our project, we are happy and satisfied with the prospect of a more ideal system that we can propose with the very simple fix of replacing a single, third party component, and then optimizing the architecture of the system for this new part.

Along with redesigning around this new generator, we learned a lot from the constructionof our project that we could apply to this new design to both speed up the process and improve the quality of the final product. A big part of this was understanding just how much the glue we used expands when drying. This resulted in glue ending up in parts of the project where glue didn't belong and caused harm to our system. The largest hurdle this created was when we glued the lower connector piece of our handcar system to the axle, glue spread out, clogging up the bearing, and gluing the piece to the wooden base. Obviously, this is not what we wanted as it created massive amounts of friction between the piece and the wooden base, meaning not only was a lot of energy lost in attempting to overcome this friction, but also a lot of extra force was applied to the rather brittle connector rod of the handcar system, challenging its structural integrity. While we were successful in making the piece moveable once again, we could not remove all sources of friction at this point in the system, ultimately creating a loss in energy transfer and indeed snapping our connector rod.

Thankfully, using scraps from the metal rod usedto create the axle, which was the same diameter as the 3D printed connector rod, we were able tocreate a new connector rod of much higher structural integrity, yet had the drawback of being a part of much lower precision. Surprisingly enough, this still worked well enough to create the results discussed above.

Our original design had incorporated an additional two feet on either side of the center beam where the users would sit, and more closely resemble the length of a seesaw you would find at a park. Making our project eight feet long was going to make it virtually impossible to transport from workspace to storage to classroom, so our solution was to attach the remaining two foot pieces of the seesaw with hinges that allowed these parts to fold over onto the rest of the center beam when not in use and being transported.

However, once we fully assembled the project with the eight foot center beam, we realized that with the way we hadthe hinges attached, they would have to support the weight of their respective side's two foot extension and more importantly, the weight of the rider on that side when fully extended. We deemed this extremely unsafe, and thought of a new way to attach the hinges. Our solution was to move the support pieces you see towards the end of either side of the final center beam to the end, and replicate this on the end of the two-foot extension piece on the side that will connectto the main part of the center beam. We could then attach door-hinges to these two faces in a waywhere the hinges would be closed when the beam was fully extended and opened when folded for transportation/storage. Unfortunately, this realization came too late in the construction processand the idea was scrapped for the sake of time.

Conclusion

Currently, the electricity generating seesaw works inconsistently and not efficiently. Our project parts broke almost every time we tested it. We analyzed our energy generation data and made a few conclusions about it. We were satisfied with our results, but if we continued working on the project, we would have much room for future improvement. Something we would improve upon is to use much stronger materials in the build of our project. We would most likely swap out the wood we are currently using because it bowed and water damaged. Another way we would modify our building materials is by removing all of our 3D printed parts and replacing them with metal parts instead. Every single one of our plastic parts either broke or gave us other problems during construction, and they were overall detrimental to the success of our project. Our motor was also a significant source of the issues because we were not using a generator. After all, there was a massive amount of lost energy. Some general quality of life things we would add are seats and handles to improve the actual seesaw experience. We would also add a plastic shield over our gears to disallow people from sticking their hands into the gears and being seriously injured.

Acknowledgements

We would like to acknowledge and thank all of the incredibly talented people who made this project possible, including, but not limited to Professor, Mr. David Hunter, and the entire staff of the First Year Engineering Learning and Innovation Center.

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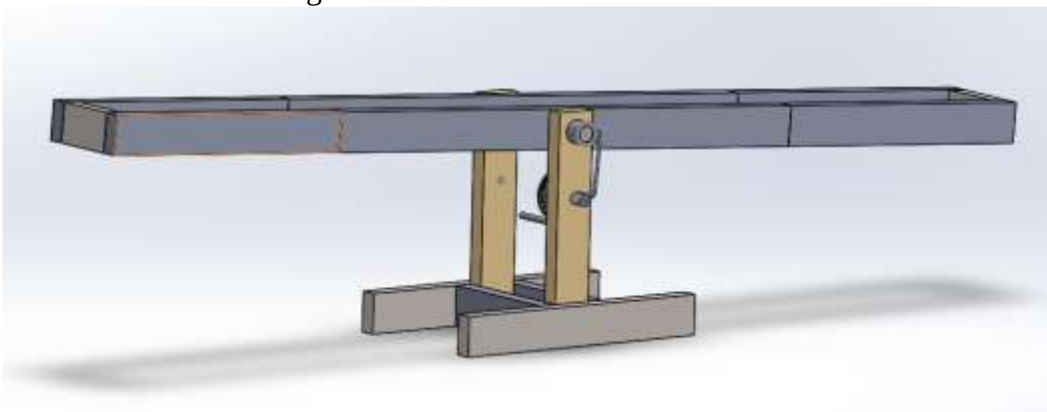
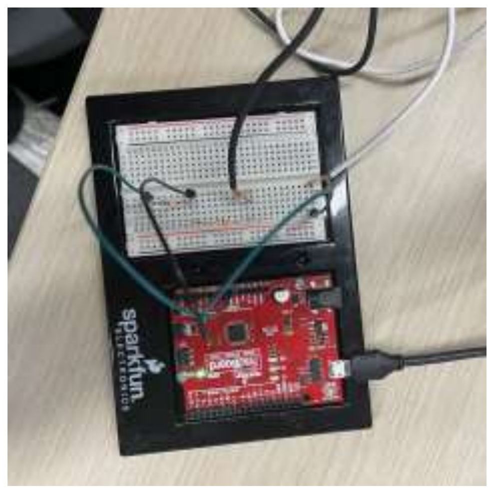
Appendices

Appendix 1: Solidworks Design



Appendix 2: Arduino Board Construction and Generator Testing



Appendix 3: Testing

Appendix 4: Arduino Code for Measuring Voltage

```
const int VoltMeter = 2;
float V = 0.00;
float mV;
float sum = 0;
float n = 0;

void calculate_voltage()
{
    float R1 = 330;
    float R2 = 330; float RT = R1+R2;
    float v_ref = 5.00;
    float resistor_ratio = 0.00;
    float adc_value = 0.00;
    float voltage = 0.00;
    resistor_ratio = (R2 / (R1 + R2));
    for (int i = 0; i < 20 ; i++)
    {
        adc_value = adc_value + analogRead(VoltMeter);
        delay(3);
    }
    adc_value = adc_value / 20;
    voltage = ((adc_value * v_ref) / 1024);
    V = voltage / resistor_ratio;
    mV = V * 1000;
}

void setup()
{
    Serial.begin(9600);
}

void loop()
{
    calculate_voltage();
    sum += mV;
    n++;
    float average = sum/n;
    Serial.print(mV);
    Serial.print(" mv ");
    Serial.println(averag); delay(1);
}
```