Wheel Surfer

A Device to Recharge Batteries from Mechanical Motion

A Technical Report submitted to the Department of Mechanical and Aerospace Engineering

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Dylan Ishikawa
Spring, 2020

Technical Project Team Members
David Bratz
Jonathan Moon
Michael Shiu

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature Dylan S. Ishikawa Date 4/29/20
Dylan Ishikawa

Approved Michael E. Momot Date May 1, 2020
Michael Momot, Department of Mechanical and Aerospace Engineering

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Advisor
Professor Michael Momot

Class
MAE 4610/4620

Date Submitted: April 29, 2020

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Abstract

The smartphone has proven to be an integral part of our daily lives, in work and leisure, and will continue to play this role in the coming future. These phones are constantly improving in processing speed and storage space but one aspect that lags behind is the battery life. Even the best phones have a hard time lasting the full day under constant use. Although charging outlets are becoming more accessible for public use, they restrain the user from moving to places or separate the user from their phones.

This project will tackle the current issues regarding phone batteries while finding an environmentally friendly means to do it. This product, the “Wheel Surfer”, is a bicycle gadget that utilizes the mechanical energy from the bike and turns it into electrical energy that powers a portable battery which then charges the phone. This is a renewable source of energy that takes advantage of the energy already exerted from bicycle riders in their travel to work or leisure.

The product is meant to be for the outdoors and so will have protective components to ensure its durability during inconvenient weather. The product will be streamlined in order to avoid restrictions to the movement of the bicycle. It is easily attachable to any standard bike and fits the needs of any biker who uses a phone.

Introduction

In the current technological era and work culture, efficiency and time are crucial assets to daily life. Students and workers alike narrow their focus on how well things can be accomplished, as well as how quickly the tasks can be completed. In attempts to maximize efficiency, several factors need to be considered. The first component is time spent commuting to and from the workplace or school. In walking or driving, people head to their destination incapable of performing other meaningful tasks. The second component is cellular devices, more specifically, the battery life. Smart phones have grown to become integral parts of both social and work aspects of life that not having access to a phone would decrease one's efficiency. Admittedly, smartphones have gotten stronger battery life throughout the years but a dead battery will always be something to consider at the start of one's day. Alarming people of this issue has led to the development of a device that will mechanically charge a battery, providing both energy and time efficiency.

According to the Center for Climate and Energy Solutions (C2ES), renewable energy in the United States is the fastest-growing energy source, accounting for 10% of total energy consumed in 2016. It is projected to grow 2% annually for the next 25 years. In the transportation sector, ethanol and biodiesel make up 22% of total renewable energy consumption. Amidst the various renewable and nonrenewable forms of energy production, mechanical energy from human movement is often overlooked. With the increase in portable electronic devices, portable power is the solution to outdoor electricity use, but storage devices are bulky and many can't be recharged without an outlet. Generators are mainly powered by fossil fuels and are noisy and polluting. Finding a way to transform significant amounts of mechanical energy in ways that do not hinder mobility and comfort is crucial in outdoor recreation and in regions where clean, reliable energy is not prevalent.

Other projects aimed to find similar means of charging a battery but have not been as efficient. Ranging from small energy output to unrealistic sizes and non-streamline structures. There was a prior project where the source of kinetic energy would come from a small fan attached to the side of a bicycle handlebar. This device would induce too little energy while not being streamline and disrupting maneuverability. Unlike that project, this device will convert enough energy while leaving the user undisturbed.

The project is called “The Wheel Surfer”. The basic structure of the device encompasses two generators in the form of DC motors, attached to a spindle wheel, all enclosed in a plastic case. The spindle wheel will rest on a bicycle wheel and will turn and drive the generators as the bicycle is in motion. The device takes advantage of the bicycle’s cyclic movement and uses the kinetic energy induced to rotate the spindle wheel, thereby the generator and then sending that electrical energy to the battery. The project focuses on resourcefulness and addresses the common issues in the modern era of technology as well as the global movement towards zero-emission energy. By creating a device that can be implemented into a popular means of transportation, the device can appeal to a large demographic, as well as inspire zero-emissions gadgets that capture the unused energy of movement.

Specifications

The original specifications of the Wheel Surfer project was to create a device that can generate enough power to charge a small electronic device such as a portable power bank or a smartphone. The goal was to design a marketable product using detailed drawings and SolidWorks 3D CAD renderings in the planning process. Techniques such as comparing the pros and cons of various designs and establishing a timeline for the project were used to ensure a superior product and effective use of time. Furthermore, a prototype will be constructed and tested for functionality and break-resistance. Several iterations will ultimately culminate in a final version of the product that is optimized based on testing and feedback.

The project is broken into two major components: the generator and the phone mount and electrical assembly. For the generator, some goals were to include two motors to ensure sufficient power produced. Also, the generator was decided to be rear-mounted to decrease accidents and keep the product from interfering with the user. The generator had to be able to produce sufficient power under normal riding conditions, which was determined to be around a riding speed of 10 miles per hour. It was also important that Wheel Surfer perform well in various terrains other than traditional pavement, where vibrations and random jolts of force may come into play. The total weight of the product was also crucial to maintain the portability aspect, as well as not significantly increasing the effort of the biker.

The phone mount and electrical wiring part of the project was just as important in ensuring a user-friendly device. The phone mount must be securely located where the user can still have easy access to their phone, as well as not interfering with pedaling and steering. This is the same specification for the wiring system that connects the generator, which is located at the rear of the bicycle, to the phone mount. Lastly, weather-proofing and shock resistance was important for both the generator and the phone mount assembly.

To make the product easy to use, we decided to use a female USB port as the output connection, which is a fairly standard connector used to charge many phones and other devices. The voltage found in the output of USB devices is 5 Volts, which we decided would be a relatively low and achievable voltage within the scope of the project. The ideal current output to charge a phone is approximately 1 Amp, but less current will still charge the phone at a slower rate. Although 5 Volts is not considered high voltage, 1 Amp is high enough current to limit material selection.

At the conclusion of the semester, in part due to complications with the academic calendar due to Covid-19, a final product was not produced. However, the first prototype of the project was able to meet many of the specifications set forth at the start. The generator assembly was able to produce a sufficient current that could charge a phone even at relatively slow wheel rpms. The generator was enclosed in a 3D printed plastic shell, which was able to pass a drop test, indicating the durability of the product. Also, the prototype weighs just over 2 pounds, which is quite reasonable. The mounting system for the prototype, however, did not meet the specifications fully. With a lack of a quick release clamping system, it was difficult to secure the Wheel Surfer to the seat post. Also, the clamp was not exactly the right diameter, so there were issues with the generator rotating left and right. The phone mount was purchased as an OEM part and did meet the specifications laid out. It was a centrally secured mount that is secured at the middle of the handlebars. In terms of electrical wiring, the wires were run from the back tire to the front of the bike, similar to how the brake wires are run. This proved to be an effective solution and did not interfere with normal operation of the bicycle. Weather-proofing was met with the well-insulated wires as well as a waterproof phone mount. The generator was enclosed by the plastic cover, so light rain and splashes were definitely accounted for, although water testing was not implemented.

Project Summary

This section of the report will introduce the working prototype. This includes the generator, phone mount, and portable power bank.

Figure A1: Wheel Surfer mounted on a bike

This picture shows the Wheel Surfer attached to a mountain bike. The product is relatively low profile and is tucked away behind the user. The device is designed to be mounted to the rear tire only.

Figure A2: Close up view of Wheel Surfer mounted on a bike

This close up view of the Wheel Surfer shows the attachment point to the seat post. As well as the pivot point in the bracket and arm assembly, which allows the prototype to remain in contact with the rear tire at all times. Once the clip is firmly attached, the force of gravity on the weight of the generator keeps it pressed on the tire. In the case of any vibrations coming from the tire, the pivot point allows the Wheel Surfer to absorb these vibrations. Also, different distances between the seat post and tire will not be an issue due to the pivoting nature of the bracket.

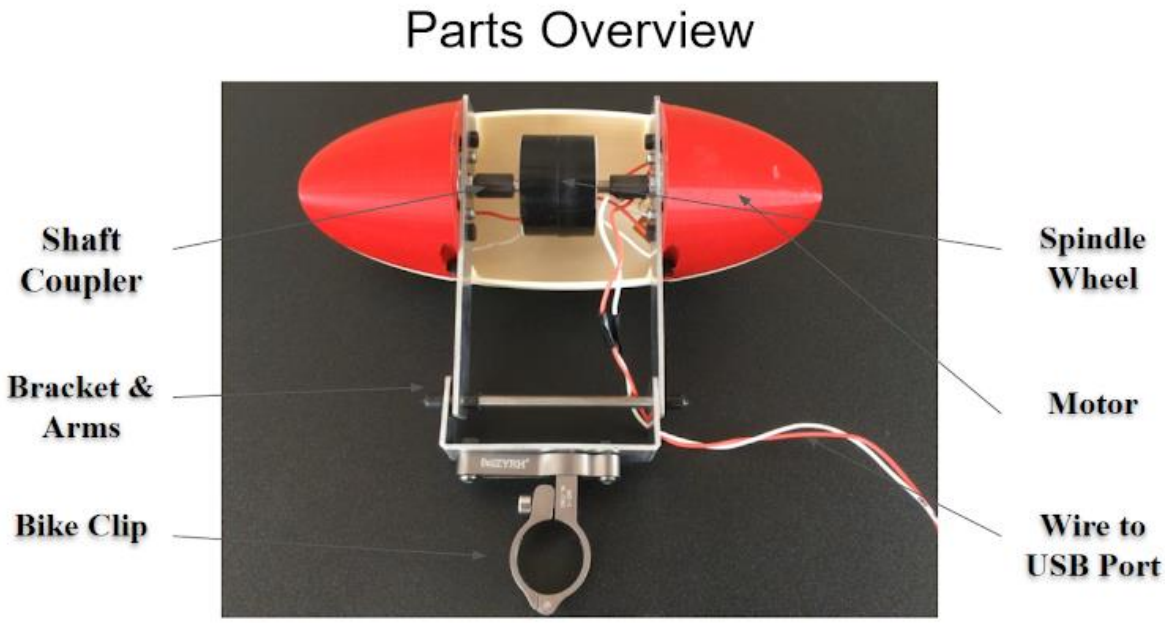

Figure A3: Parts of the generator assembly.

This figure helps to break down and introduce the major components contained inside of the Wheel Surfer. In this picture, the device has been flipped over and is showing what it looks like from the bottom up. Starting with the spindle wheel, it is centrally located and has a metal shaft running through its center. On either side of the spindle wheel are the motors contained within the red caps. To connect the motors to the spindle wheel, which is in charge of driving the motors during operation, two black shaft couplers are used to connect the larger spindle wheel shaft to the smaller motor shafts. The shaft couplers are included rather than permanently connecting the motor shafts to the spindle wheel shaft because this allows the user to replace specific parts in case of damage or defect. The spindle wheel is projected to be the component that needs the most maintenance or replacement due to its direct contact with the tire. Moving downwards, the bracket and arms of the device are machined from aluminum and serve as the structure to connect the bike clip to the generator components. The bike clip in the prototype as seen above does not have a quick release, which is an important change for the final design. The bike clip is easily attached to any bicycle and small adjustments to the attachment height can be made to ensure optimal performance. The electrical wiring comprises two insulated wires that are connected to the motors and terminate at a dual USB port.

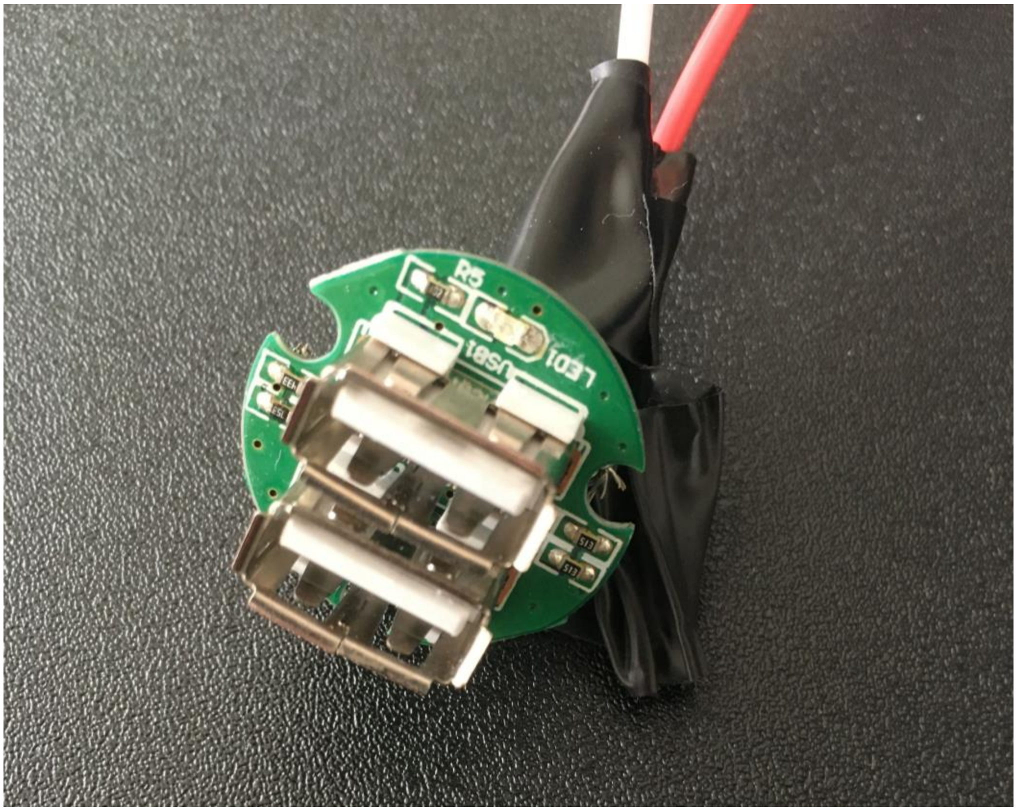

Figure A4: Dual USB Port

This is the dual USB port that is found at the end of the wiring from the motors. More information on the electrical circuitry can be found later in the report. The dual USB port allows for up to two USB powered devices to be charged. In the final design, the USB port will be connected to an OEM power bank that is situated in the phone mount.

Figure A5: Phone Mount

The phone mount shown above is an OEM part purchased from Amazon. The pouch is waterproof and has a clear screen that allows the user to access their phone while the phone is in the mount. There is plenty of storage space in the pouch to allow both a phone and a battery.

Figure A6: Portable Power Bank

The portable power bank is also an OEM part purchased from Amazon. This battery is a 7.5 ounce, 10,000 mAh device that can charge up to two devices at once. It is approximately 5.5 by 2.7 inches and has a thickness of 0.6 inches.

Detailed Design

Parts List

Final Parts List and Cost for Prototype

Part #	Name	Qty	Cost Each With Shipping	Cost total for Production	Source
100	Motor/Generator	2	16	32	Amazon
101	Spindle Wheel	1	3.51	3.51	McMaster Carr
102	Spindle Wheel Shaft	1	4.11	4.11	McMaster Carr
103	Clip Attachment Shaft	1	5.97	5.97	McMaster Carr
104	M5 Lock Washer	10	0.03	0.30	McMaster Carr
105	M3 Screw	2	0.04	0.08	McMaster Carr
106	Wheel Attachment Arm	2	`0.95	1.9	McMaster Carr
107	Bike Clip Mount	1			Same part as 108
108	Bike Clip Ring	1	8.44	8.44	Amazon
109	Clip Bracket	1	0.95	0.95	McMaster Carr
110	M5 Nut	10	0.02	0.2	McMaster Carr
111	M5 Bolt	10	0.4	4	McMaster Carr
112	Shaft Coupler	2	9.8	19.6	McMaster Carr
113	End Cap	2	0.04	0.08	McMaster Carr
114	Generator Cover Top	1	27.98	27.98	3D Printed MAE Lab
115	Generator Cover	2	0	0	3D Printed Alderman

	Bottom				MakerSpace
201	Phone Mount	1	15	15	Amazon
202	Power Bank	1	20	20	Amazon
301	Schottky Diode, 1N5822	1	0.81	0.81	Digikey
302	L78S05CV High Current Voltage Regulator	1	1.01	1.01	Amazon
303	100uF Capacitor, 50V	1	0.86	0.86	Digikey
401	Wire, 18 gauge (10ft)	1	1.81	1.81	McMaster Carr
402	Electronics Board	1	1.96	1.96	McMaster Carr
	Total Cost:			146.66	

Bike Clip Attachment

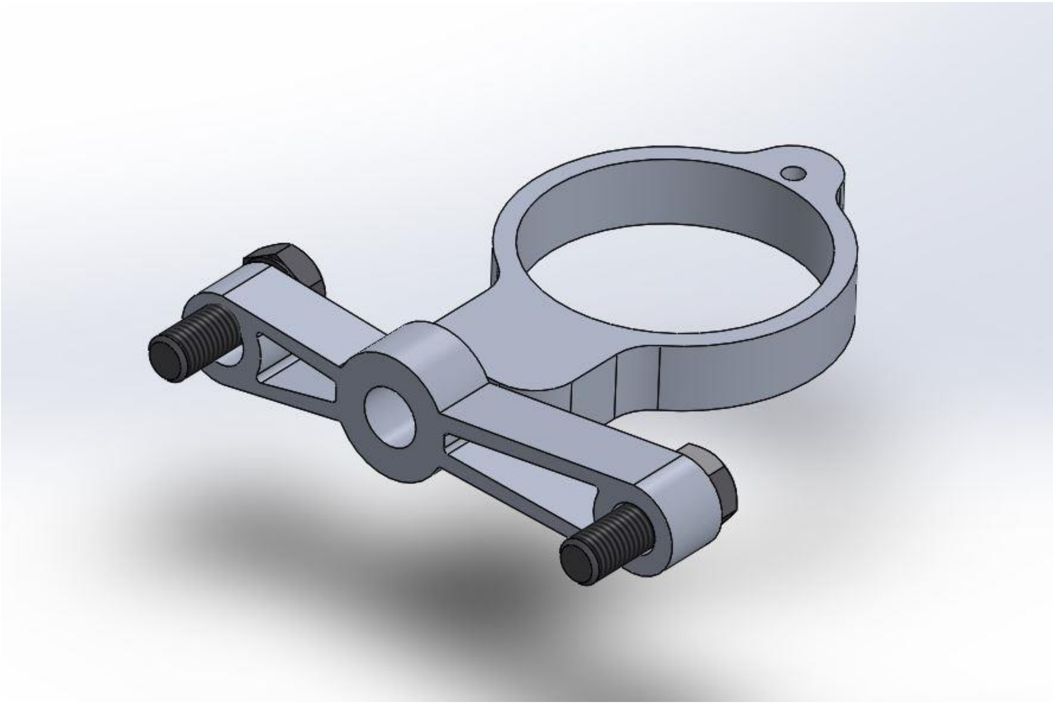

Figure B1: Bike clip attachment.

The clip shown here is a standard clip used on bikes, mainly for mounting water bottle holders. Rather than machining this part, we decided it would be more cost effective if this part was outsourced. The clip we selected includes a rubber insert to adjust for different diameter bike seat posts. We also selected a quick release clip, which will allow users to easily add or remove our product from their bikes. It will also allow the user to quickly add or remove our product to their bike. The clip attaches to the rest of our assembly using two M5 screws, which are shown.

Bracket and Arm System

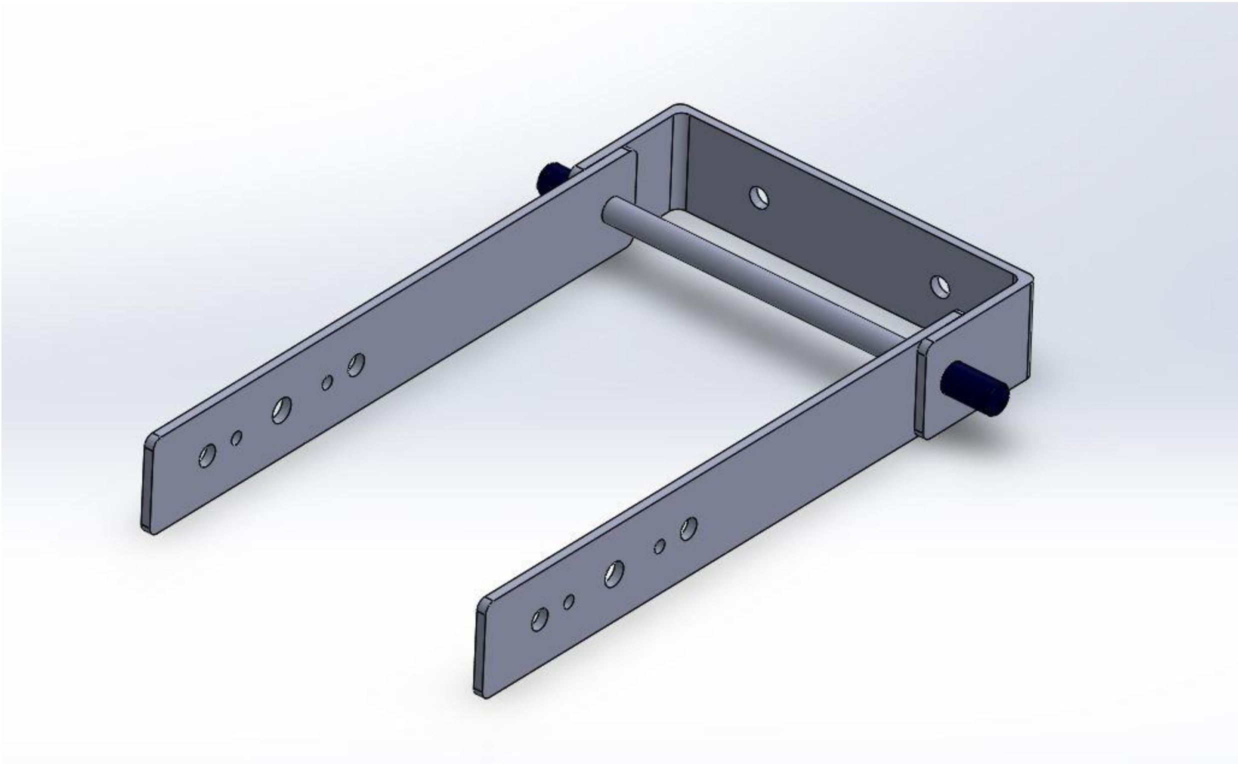

Figure B2: Bracket and arm system.

The bracket attaches to the clip using the two screw holes. A ¼” diameter shaft is used to connect the two arms to the bracket. It is kept in place with two rubber end caps. We found it is relatively difficult to remove the end caps once they are on the shaft. Given that, there is no concern that the end caps would fall off while the product is being used. The shaft and hole is designed to be a clearance fit, which allows the arms to rotate. This allows our product to be compatible with a wide variety of bikes. Initially, a torsion spring around the shaft and connected to the arms was proposed to keep the rest of the assembly in contact with the bike tire. However, we decided that the weight of the assembly would be enough to keep it in contact with the tire. We also did not want to add more parts and costs to our design.

The arms are used to connect the motors and covers using the screw holes on the ends of the arm. Both the bracket and the arms are made of aluminum, which is lightweight, cost effective, and strong.

Spindle Wheel and Motors

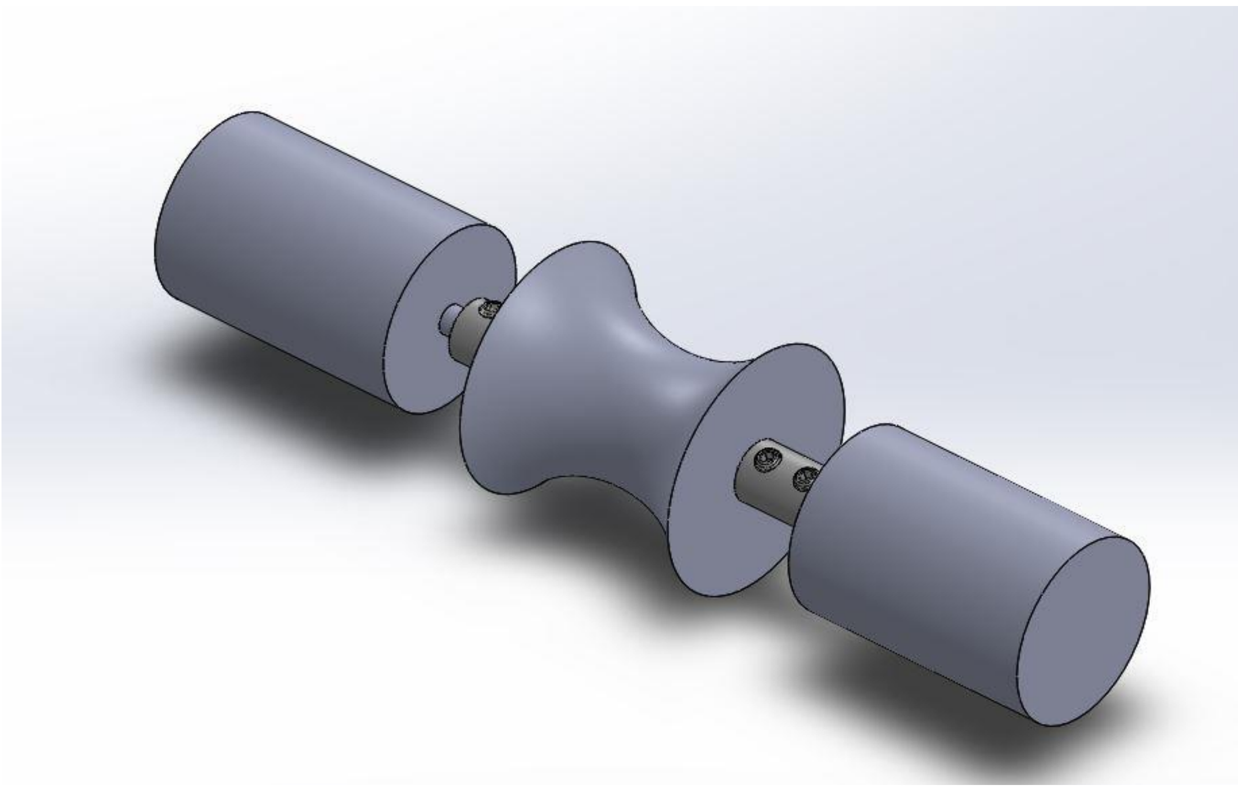

Figure B3: Spindle wheel and DC motors

Our product uses two 12V 550 RPM DC motors. Phones are usually charged using 5V and a 1A current. Given this, we selected our motors to be able to generate enough voltage and current to do this.

The spindle wheel is the part of the assembly that is in contact with the bike tire. A curve was added to the wheel to minimize side-to-side motion of the assembly while it is in use. The curve was designed to fit most bike tires, but it is not necessary for the bike tire to fit perfectly in the curve in the spindle wheel for our product to work. The spindle wheel is attached to a ¼" diameter shaft. We initially used a set screw to attach the wheel to the shaft, but this was found to be ineffective during prototype testing. Instead, we simplified the design and attached the shaft to the spindle wheel with glue, making the set screw unnecessary. The glue was much more effective in keeping the two parts attached.

Since we wanted our parts to be interchangeable, we didn't want to simply glue the motor shaft directly to the spindle wheel shaft. To solve this problem, we used a shaft coupler to connect the two shafts.

Motor Attachment

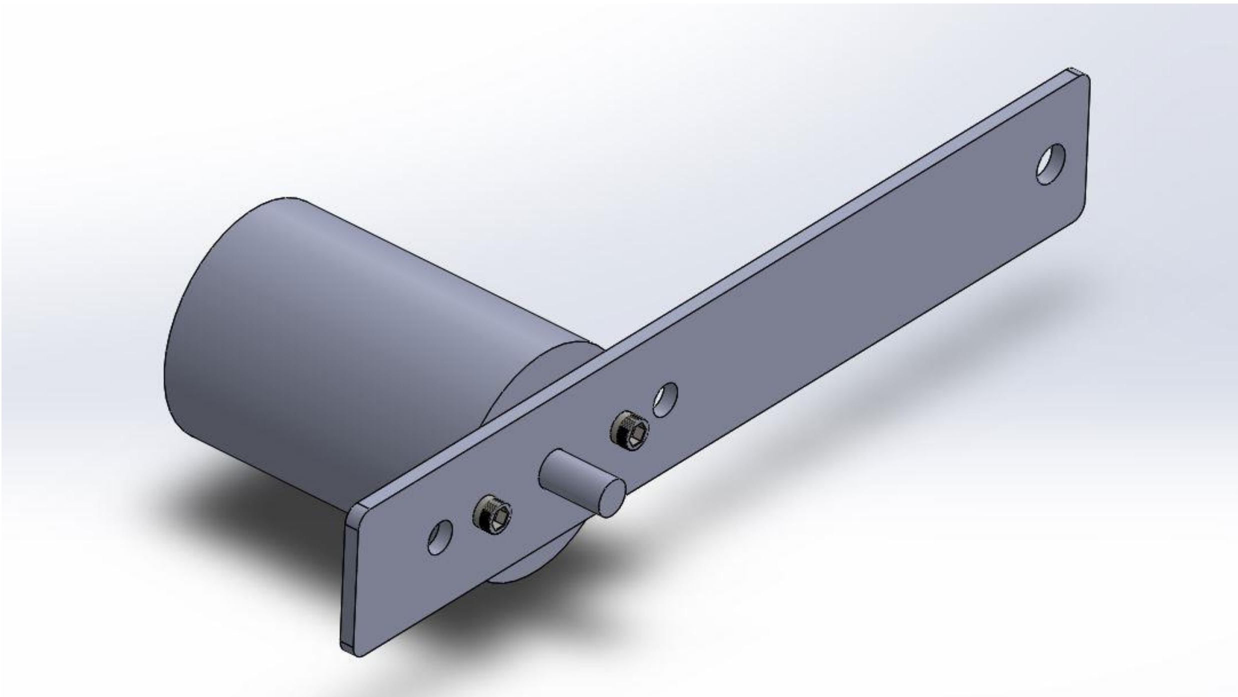

Figure B4: DC motor attachment to metal arms.

The motors we selected came with screw holes designed for easy mounting. The motors connect to the arms using two M3 screws.

Generator Cover Attachment

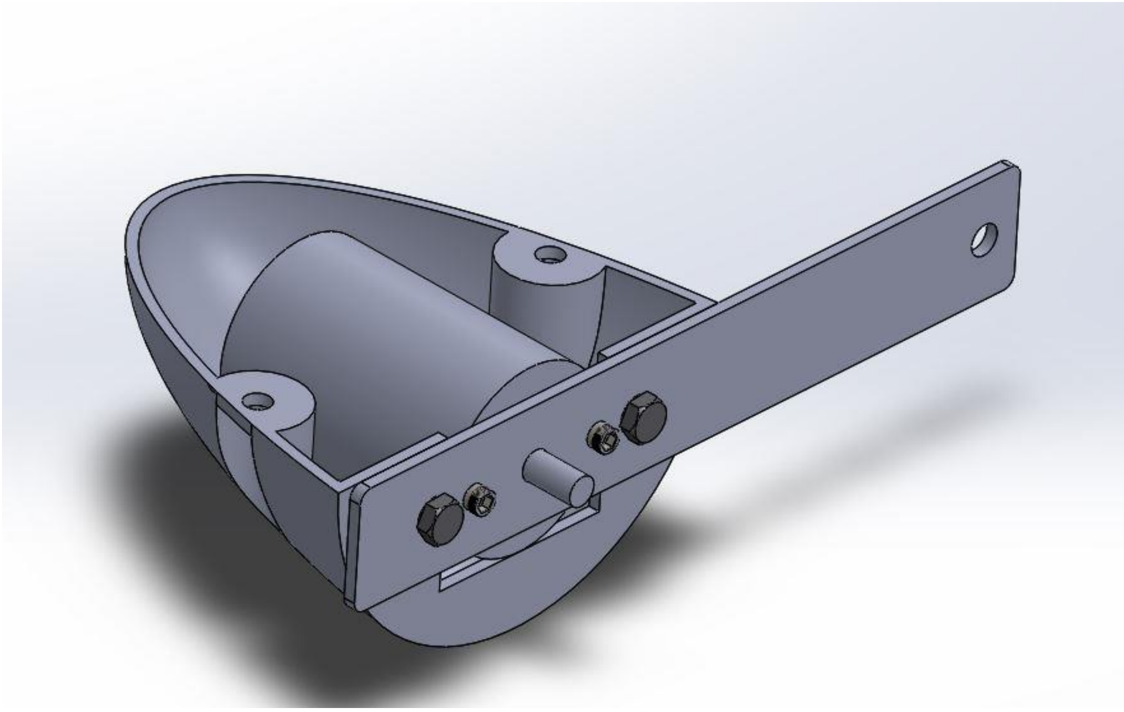

Figure B5: Bottom cover attached to arms.

The generator covers were designed to protect the motors and other electronics from direct exposure to the elements, while also being aesthetically pleasing. The part was designed to be 3D printed for our prototype, but if our product were to be manufactured, injection molding would be a more cost effective way of producing this part. The bottom cover, which is shown, connects to the arms using M5 screws, lock washers, and nuts. The lock washers were added to prevent the nuts and bolts from becoming loose due to any vibrations while the product is in use. M5 screws were selected since they are already used in other parts of the assembly. The bottom cover includes a small notch, which is not visible in this view, but can be seen in the part drawing. Instead of increasing the size of the cover, which would have increased costs, the notch was added to ensure the motor fits within the cover. The bottom cover also includes holes to attach the top cover.

Generator Cover

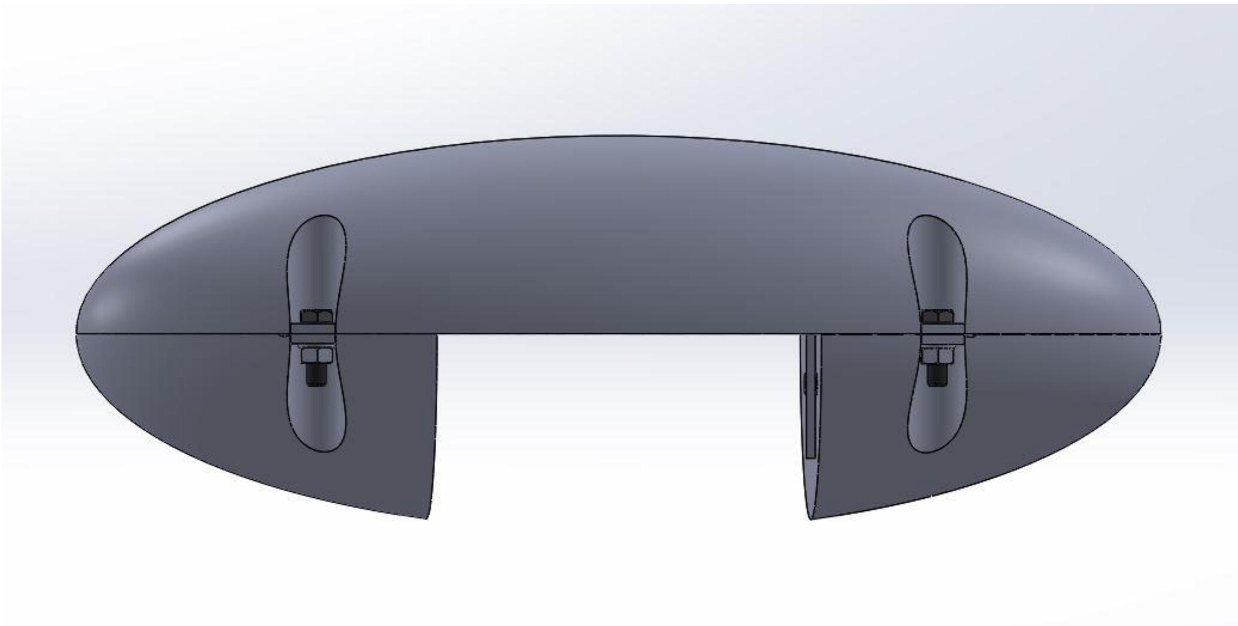

Figure B6: Generator cover top and bottom(s) attached together.

The top cover attaches to the bottom cover using M5 screws, lock washers, and nuts. We decided to continue using the M5 screws and nuts since they are already used in other parts of the assembly. The indents into the cover where the screws and bolts are were widened to allow for easier assembly. If the nuts are properly tightened, we do not believe there is a significant risk of them becoming loose while the product is in use. We did not encounter any problems with nuts becoming loose during prototype testing.

Electronics and Power Filtering

A small circuit must be used in order to filter the power coming from the motors and make it safe to connect USB devices to. The circuit consists of a diode, a capacitor, and a 5V regulator chip before connecting to the female USB port. The purpose of the diode is to protect the circuit and the device against any negative current that could accidentally flow through the circuit if the wiring was incorrect or if the user spun the generator in the wrong direction. A 1N5822 diode was chosen because of it's high maximum voltage breakdown limit of 40 Volts, current rating of 3 Amps, and low peak reverse voltage. A 100 μF filter capacitor was used to smooth out any ripples of current coming from the generator ahead of the voltage regulator, which should help keep the current coming into the regulator steady and more resilient under transition conditions. Lastly, the L78S05CV chip was chosen as a 5V regulator due to its high current capacity. 18 gauge wire was chosen for all the connections due to its current ratings and relatively small size.

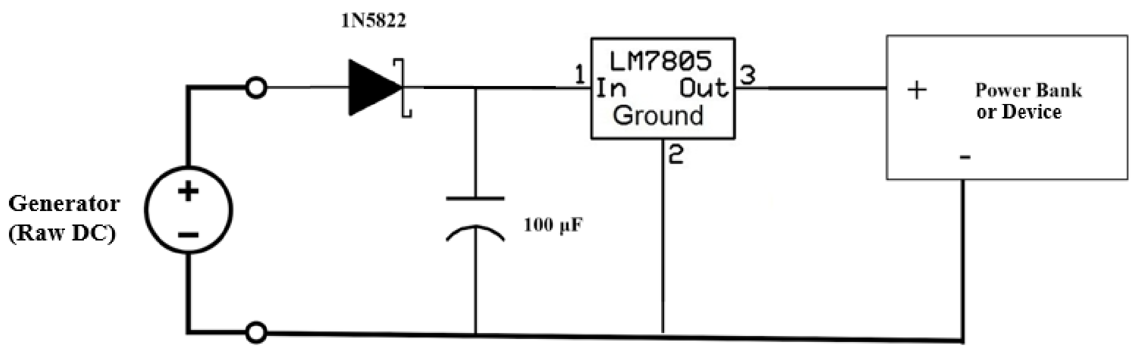

Figure C1: Power circuit schematic.

List of Codes/Standards Used

Our product contains a number of components that follow industry standards. One group of components are the M5 bolts and nuts as well as the M3 screws that are used to construct the generator assembly that sits on top of the back wheel of the bike. This collection of hardware follows ANSI/ASME standards and were chosen due to the general use of this type of hardware in bike accessories. This would allow for the nuts and bolts to be manipulated by a minimally equipped bike user or easily replaced by a bike mechanic. To determine the size of clearance holes for these bolts, ASME B18.2.8 was used. ASME B18.2.8 is the standard for clearance holes for bolts, screws, and studs.

Both of the shafts are intended to have a clearance fit. To accomplish this, a loose running fit was selected and shaft basis design was used (C11/h11). For a shaft size of 0.25 in, the hole size was calculated to be 0.255 in with a tolerance of +/- 0.005 in. This follows ASME 4.2b, which is the standard for preferred metric limits and fits. Values were calculated and then converted to inches.

The two motors used for generating electricity follow NEMA standards according to the manufacturer. The recommended motor use temperature is 0℃ - 70℃, and the recommended storage humidity range is 15% -90% relative humidity.

We used ABS plastic for our 3D printed parts. This material follows ASTM standards ensuring that it will be able to withstand standard impact forces as well as hold up in adverse environmental conditions. In addition, the aluminum used in our product follows ASTM standards.

Design for Manufacturing

In the early stages of manufacturing, the team focused on a single prototype and ensured its functionality before moving forward. The prototype consisted of several outsourced components and 3D-printed material. The list of the bought parts can be seen in the section Parts List, column "Source". While 3D-printing was the quickest way to obtain the required material, it only serves to manufacture a limited number of products as the price ranges significantly increase. Given the "Wheel Surfer" will be mass produced, the alternative to 3D-printing would be injection molding. Injection molding would net a far lower price while producing large amounts of the parts needed.

Many of the ordered parts needed slight adjustments to perfectly align with the team's vision of the product. Many of these adjustments were made with the help of University of Virginia's Student Experiential Center- Lacy Hall. These are the following parts:

- Part 101, the Spindle Wheel, is 2'' diameter and 12'' long White Delrin Acetal Resin Rod that was cut down to a 2'' length rod with the same diameter using a horizontal bandsaw. In order for Part 102, the Spindle Wheel Shaft, to fit a ¼'' diameter hole was drilled at the center of the circular face all the way through using a drill press.
- Part 102, the Spindle Wheel Shaft, is a ¼'' diameter and 3'' long rotary shaft made of 12L14 Carbon Steel. The shaft was sawed down to 2.5'' in length using a handsaw.
- Part 109, the Clip Bracket, is .1'' thick, 6''x 12'' Corrosion-Resistant 3003 Aluminum Sheet. The shapes of the brackets were designed using the SolidWorks CAD software and cut using a water jet. The cut pieces were then bent and sanded using a hydraulic bending machine and a handheld metal filer respectively.

Design for Environment

There are several environmental considerations that were taken into account while designing the final product. To start, the “Wheel Surfer” does not depend on fossil fuels which emits greenhouse gases that are dangerous to the environment and the people living in it. This is important because despite the dangerous consequences, fossil fuels are one of the most prominent uses of energy in regards to transportation. Having a renewable source of energy that does not depend on greenhouse emissions sets the product apart while promoting the important message of environmental awareness. Unlike other transportation means that depend on long hours of charge, the “Wheel Surfer” does not have similar limitations. Another component to consider is the plastic use in the product. The top and bottom covers are made of ABS plastic which would take a very long time to decompose should the parts fall out or break on the ride without realizing. However, ABS plastic was chosen for its strong impact resistance, making it very unlikely to break apart. Also, the plastic casing is tightly secured to the aluminum brackets with M5 nuts and bolts making it highly unlikely to fall out of the bike.

Design for Safety

We do not believe there are any safety issues with our product. Our product will be able to withstand normal vibrations from riding a bike and should be durable enough to withstand a crash. Exposed parts are made of plastic and metal, so it should withstand sun and rain exposure. Our product was also designed to avoid being caught in the bike tire spokes or the chain. In addition, our product will not significantly increase the difficulty of riding a bike due with regards to its weight and friction against the rear bike tire.

The only small parts in our product are nuts, bolts, and lock washers. Once attached on a bike, these parts should pose no threat of ingestion by small children. If properly tightened, the nuts and bolts should not be at risk for coming loose. Lock washers were added to prevent vibrations from loosening nuts.

We do not foresee any electrical issues with our product. All wires will be insulated and the battery has been chosen to minimize the risk of a fire or an explosion. The only exposed electrical part will be the phone charger and we believe most (if not all) users will be familiar with how to plug in a phone charger. We do not believe there is any risk of electric shock for users.

Our product has survived a drop test from a height of approximately 3 feet onto a foam cushion. The exposed metal parts of our product (clip bracket, metal arms, etc…) should survive an impact (e.g. bike crash). The plastic cover top and bottom may shatter in the event of a bike crash, but they are designed mainly to protect the motors. In the event the cover breaks, the user will be able to buy a replacement cover without having to buy another entire generator assembly.

Design for Automation

As a team, we considered the ease of assembly by designing each part with simple geometry. The four main components that we are manufacturing include the following: The generator cover, the phone mount, the wheel attachment arm and the bracket clip. The generator cover is one piece that is both horizontally and vertically symmetrical. It will not tangle with other parts and will be attached to the system with screws. The size and thickness of the part is enough to protect the generator and also hold it in place while using the minimal amount of material needed. The phone mount is horizontally symmetrical so that it will not tangle with other parts and be attached to the system with velcro. Minimal material has been used for it to hold both the phone and battery in place. Both the wheel attachment arm and the bracket clip were designed to be easily manufactured in their geometric symmetry. Both parts will be attached to the system using screws. Minimal material has been used for both parts to add stability to the system, keeping everything in place.

We designed our product with the user in mind. We selected a quick release clip so that the user can easily add or remove the product from their bike. We also used M5 screws, nuts, and lock washers for all connections except securing the motors so that the user would not need to keep track of different sized parts. Assembly should not require any additional tools other than an allen wrench, which could be included with the product, and a regular wrench. We believe all users, given instructions, are capable of assembling our product quickly, correctly, and safely.

Cost Analysis

The amount of money spent on the research, design, and construction of the prototype throughout this project was $232.71, well under the budget for this project of $400. A lot of the raw materials purchased came in bulk and were not used in their entirety for this project, and the final cost of materials that went into the final design was $146.66. This includes the free 3D printing for some components that were available to us as students at UVA. Currently, the cost of the unit is too high for most consumers, and changes should be made in order to bring the cost down. The changes we recommend are using injection molding for most of the plastic pieces, allowing the user to purchase nonessential parts separately, and to find cheaper alternatives for the motors and shaft couplers. For the final cost analysis table, these assumptions are calculated, assuming a 75% price reduction for the motors and a 50% price reduction for the shaft couplers.

Making these changes brings the cost down significantly to $74.34, and we recommend a final cost to the user of $199-225.

Injection Molding for Mass Production

Injection molding is a common method of creating cheap plastic parts in a factory setting, and would be ideal for creating the top and bottom covers for the generator. The following are calculations approximating the cost of making the top and bottom covers using data online (REX Plastics, 2013). It is assumed that tooling and machine operating cost are negligible. ABS plastic was used in this calculation at a cost of $1.29/lb.

	Large Cover (Pt. 114)	Small Cover (Pt. 115)
Volume (in3)	5.54	1.88
Weight (lb)	0.2105	0.0714
Mold Cost	$12,000	$8,500
Material Cost (per part)	$0.272	$0.092
Cost/piece for 2,000	$6.272	$4.342
Cost/piece for 10,000	$2.672	$0.942
Cost/piece for 50,000	$0.512	$0.262

Nonessential Parts and Replacements

The battery pack and phone case are considered nonessential to product use, and are multipurpose parts that may already be owned by the user. The parts are not altered or assembled in any way that creates difficulty for the user, and should not be marked up significantly in the final price like the other raw materials. Instead, we recommend that the company selling this product also becomes a dealer for the battery and phone case, selling them separately or in a package deal with the Wheel Surfer.

The current motor/generator costs $16 apiece, with two being used in the product. In order to reduce price, another DC motor with a ¼ inch shaft and similar voltage specifications that fits in the chassis will be a suitable replacement. Most motors with ¼” shafts are quite large and expensive, so using shaft adapters is another possibility. The current shaft couplers are nearly $10 apiece, with two being used in the total design. We recommend that these should be machined in house to reduce the cost of manufacturing.

Parts List for Mass Production

Part #	Name	Qty	Cost Each With Shipping	Cost total for Production	Source
100	Motor/Generator	2	12	24	Amazon
101	Spindle Wheel	1	3.51	3.51	McMaster Carr
102	Spindle Wheel Shaft	1	4.11	4.11	McMaster Carr
103	Clip Attachment Shaft	1	5.97	5.97	McMaster Carr
104	M5 Lock Washer	10	0.03	0.30	McMaster Carr
105	M3 Screw	2	0.04	0.08	McMaster Carr

106	Wheel Attachment Arm	2	`0.95	1.9	McMaster Carr
107	Bike Clip Mount	1			Same part as 108
108	Bike Clip Ring	1	8.44	8.44	Amazon
109	Clip Bracket	1	0.95	0.95	McMaster Carr
110	M5 Nut	10	0.02	0.2	McMaster Carr
111	M5 Bolt	10	0.4	4	McMaster Carr
112	Shaft Coupler	2	4.9	9.8	McMaster Carr
113	End Cap	2	0.04	0.08	McMaster Carr
114	Generator Cover Top	1	2.67	2.67	Injection Molded
115	Generator Cover Bottom	2	0.94	1.88	Injection Molded
301	Schottky Diode, 1N5822	1	0.81	0.81	Digikey
302	L78S05CV High Current Voltage Regulator	1	1.01	1.01	Amazon
303	100uF Capacitor, 50V	1	0.86	0.86	Digikey
401	Wire, 18 gauge (10ft)	1	1.81	1.81	McMaster Carr
402	Electronics Board	1	1.96	1.96	McMaster Carr
	Total Cost:			74.34	
	Optional Add Ons				
201	Phone Mount	1	15	15	Amazon
202	Power Bank	1	20	20	Amazon

Conclusion and Future Works

In general, the project and prototype were very successful in proving the concept of a bicycle generator capable of providing ample power to charge a cell phone or power bank. Our group was very pleased to find that our prototype was capable of charging a phone on the first try in testing, with no major changes from the initial design. Due to the Covid-19 pandemic, our group was unable to continue to test the prototype in casual user scenarios and make new changes or adjustments after our first prototype. However, we have gained substantial knowledge about the strengths and downfalls of the prototype, which can be used to build an improved generator in the future.

One of the strengths of our project was power generation capability. Although we were unable to get specific voltage data, the two motors produced over 7 Volts each at low bike tire speeds, which is the threshold for the voltage regulator to successfully step down to 5 Volts. The motors were wired in parallel for maximum current, and they could have been wired in series to double the voltage. This also proved that our estimations regarding motor selection and spindle wheel size were correct in providing us with the proper gear ratio, torque, and speed to optimally drive the motors. Also, the fit of our prototype onto the bike was satisfactory, and there were no major design modifications that needed to be completed in order for the prototype to mount and function properly.

There were some areas in need of improvement for our project, most notably project cost and durability. Due to the large motors and shaft size, the final cost ended up being very high, and it is questionable whether many people would be interested in purchasing this product due to the high cost. The motors in particular are likely larger than necessary for this project, and are driving the price up by their size forcing a large, costly design, as well as being expensive components on their own. The durability of this product is another concern, with the heavy motors creating stability issues and requiring design with very robust components. In testing, the product was susceptible to falling off the wheel easily, which could cause the assembly to break if it occured in normal bike use. This would be improved with a spindle wheel with a groove in it to keep the assembly aligned or with changes to the pivot arm system.

With these improvements, the general design concept could be formed into a useful product to provide charging capabilities to bicycle users. Our team was unfortunately unable to refine the design and explore the proposed improvements due to the pandemic, but we are confident that an improved design would prove functional and convenient to bicycle users. This project proved itself to not only be a proof of concept, but also an effective starting point for future design works.

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Appendices

Appendix A: Prototype Pictures

Figure A1: Wheel Surfer mounted on a bike

Figure A2: Close up view of Wheel Surfer mounted on a bike

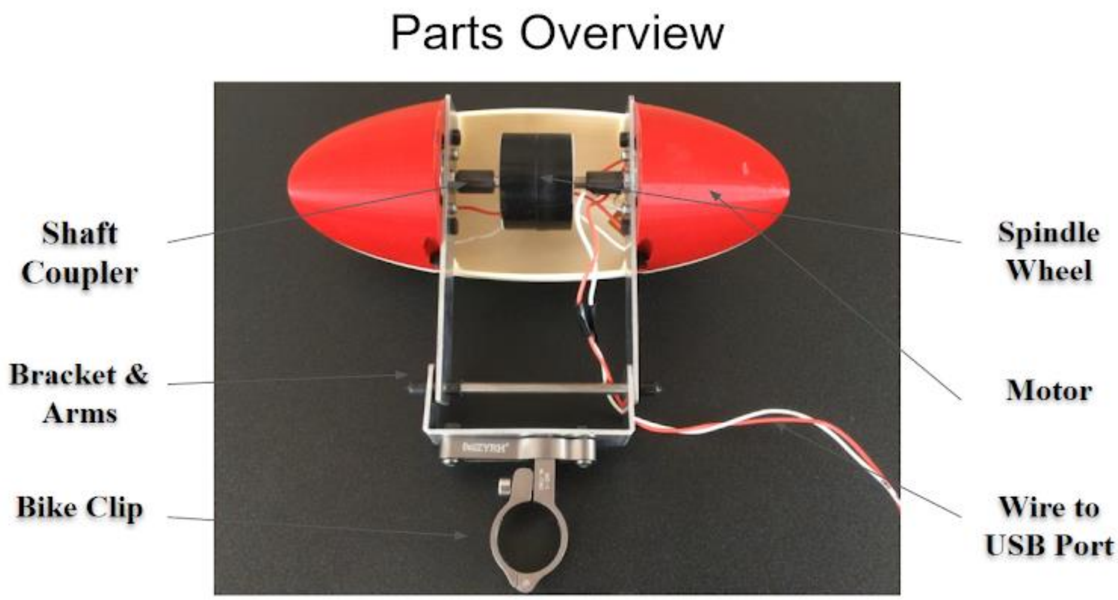


Figure A3: Parts of the generator assembly.

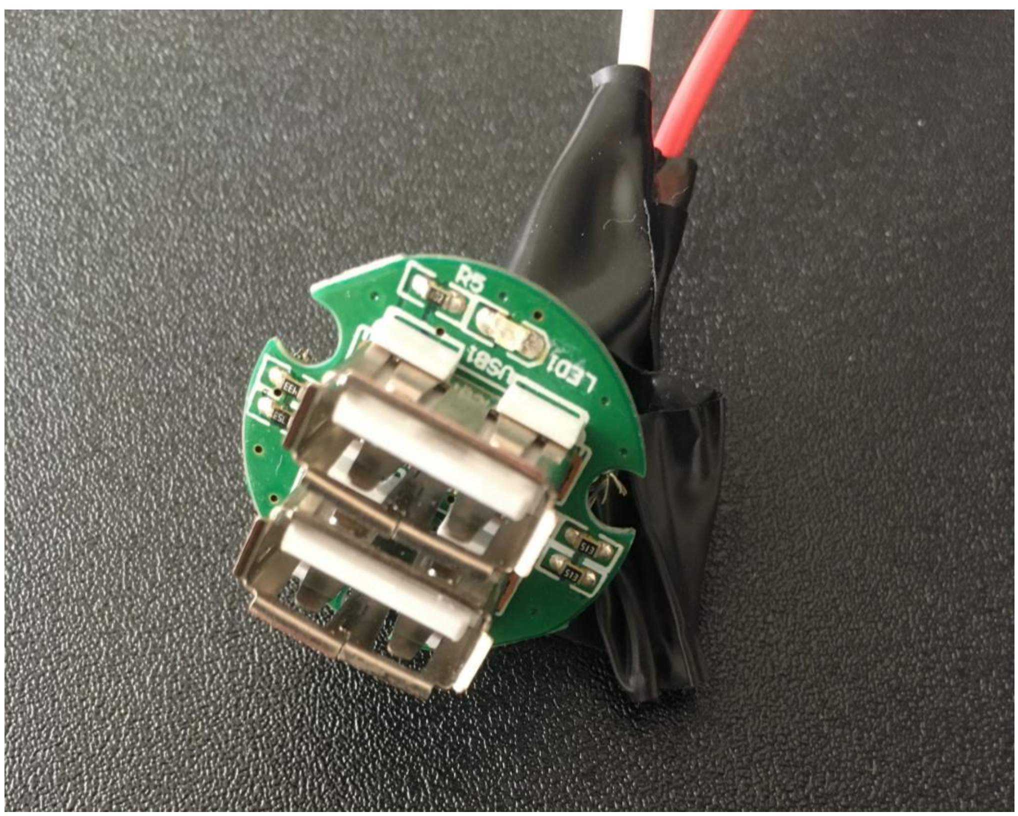


Figure A4: Dual USB Port

Figure A5: Phone Mount

Figure A6: Portable Power Bank

Appendix B: CAD Pictures

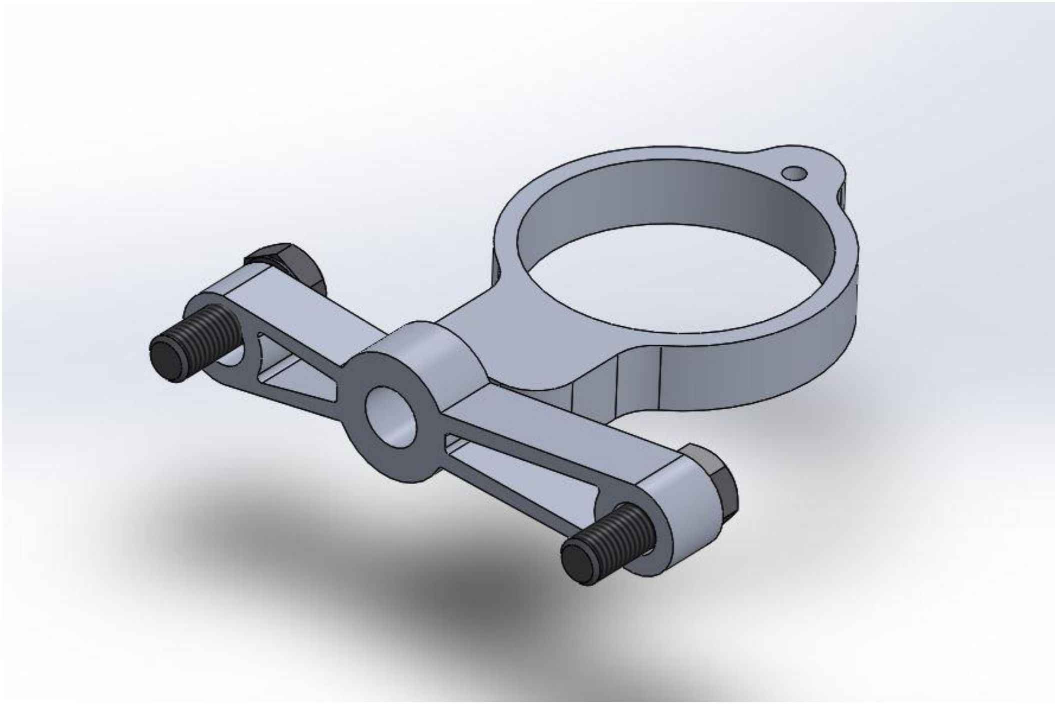


Figure B1: Bike clip attachment.

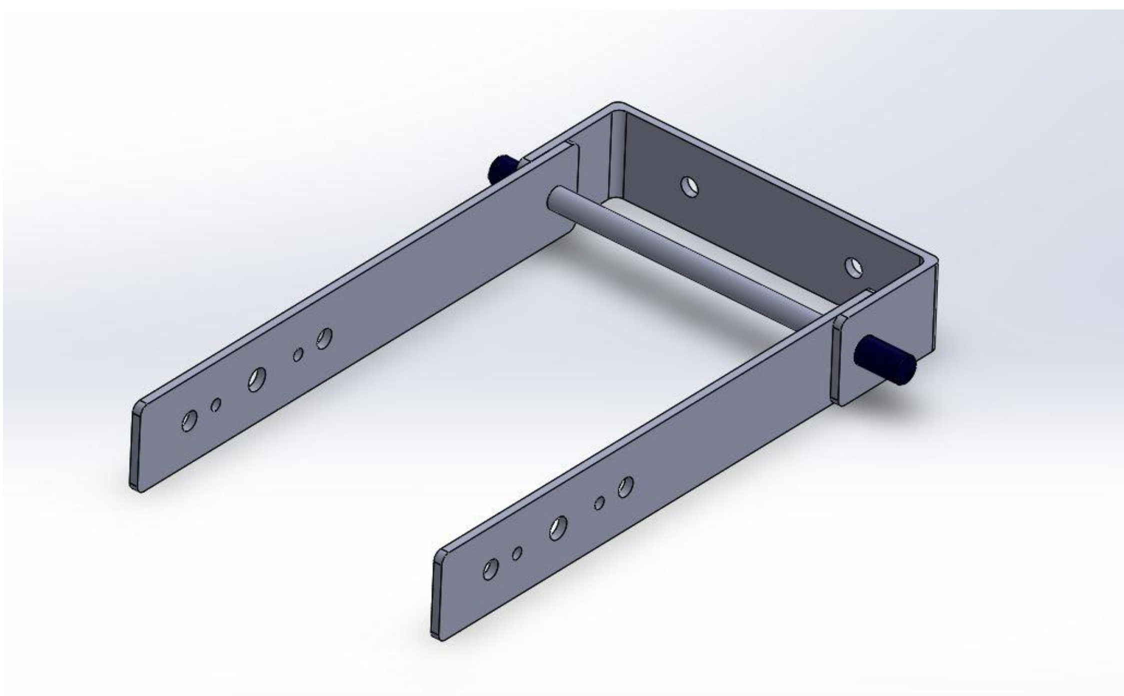


Figure B2: Bracket and arm system.

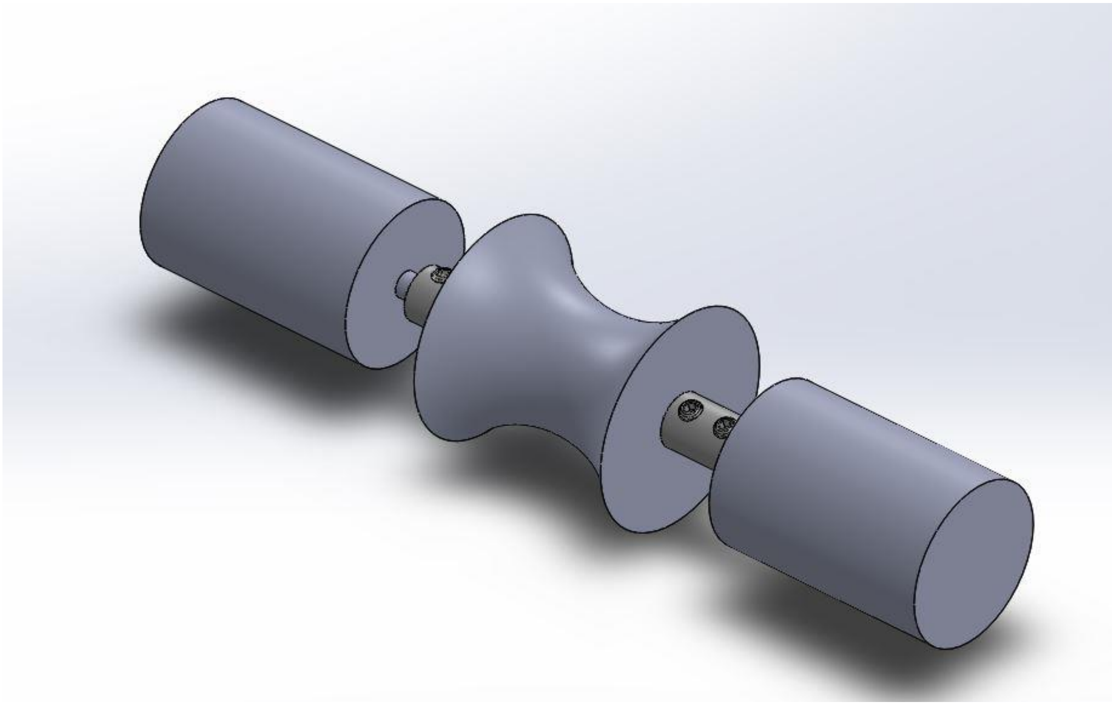


Figure B3: Spindle wheel and DC motors

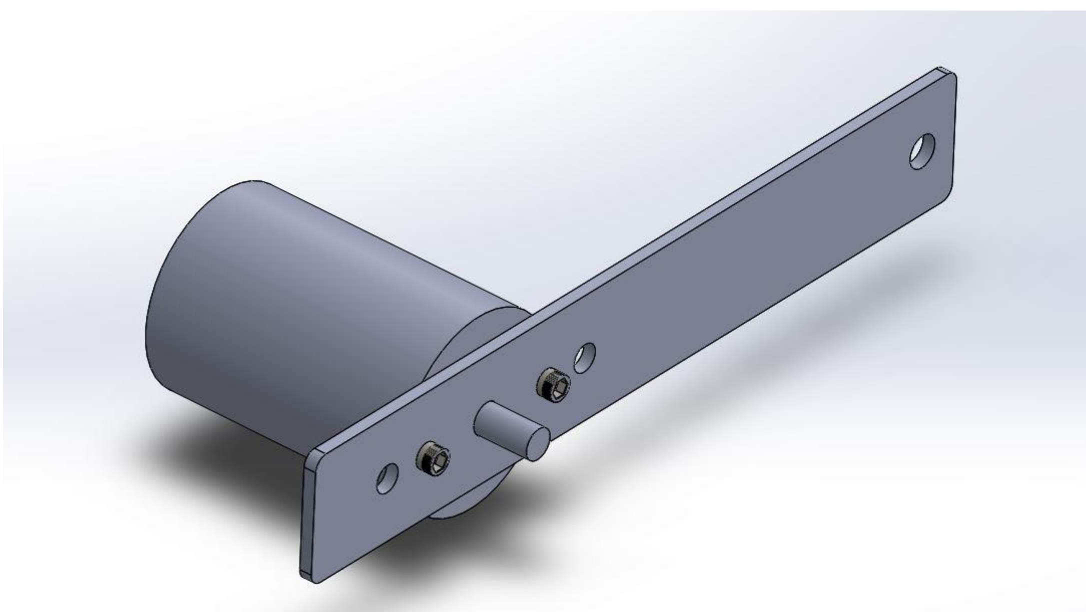


Figure B4: DC motor attachment to metal arms.

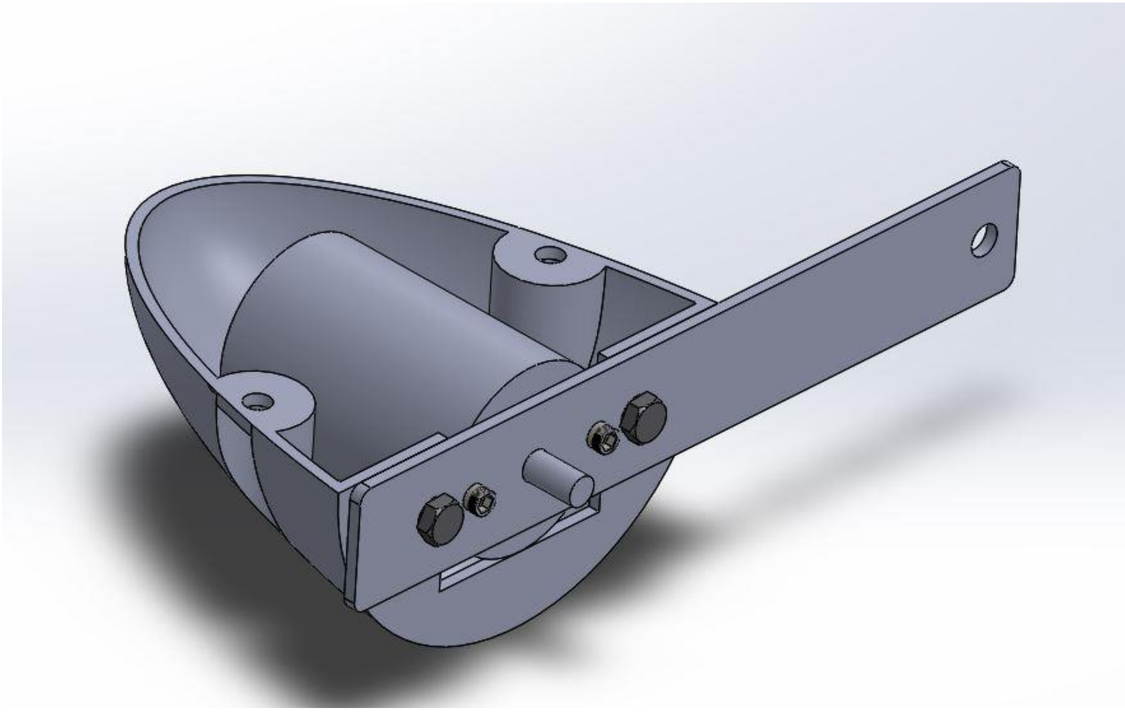


Figure B5: Bottom cover attached to arms.

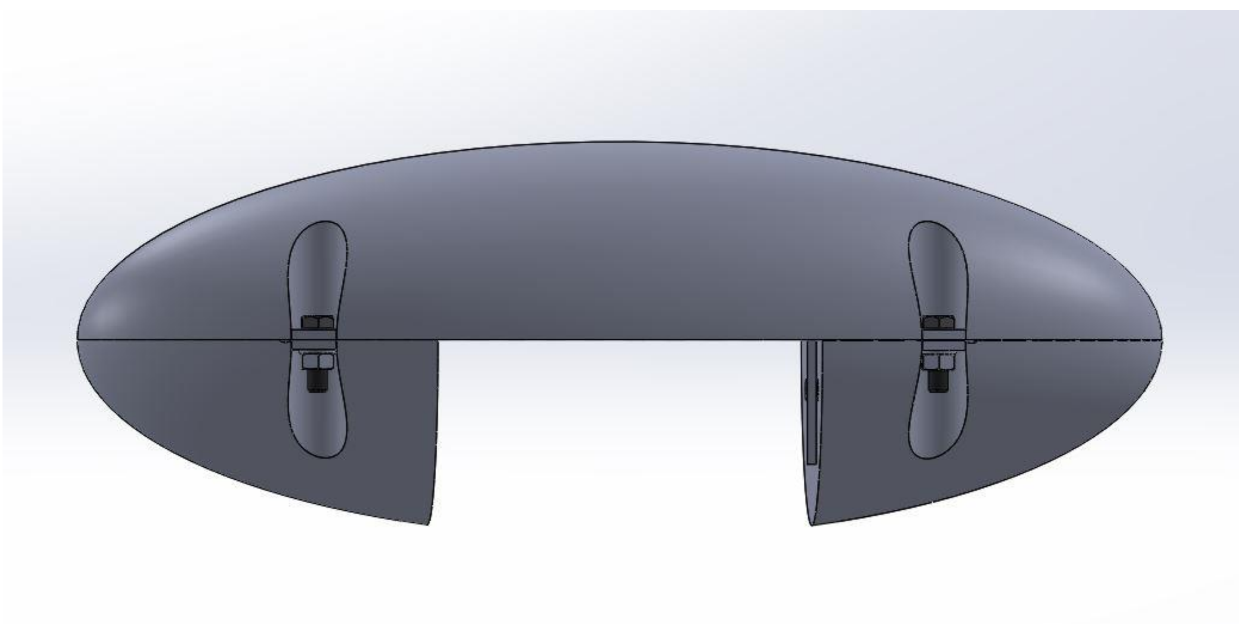


Figure B6: Generator cover top and bottom(s) attached together.

Appendix C: Electrical Diagram

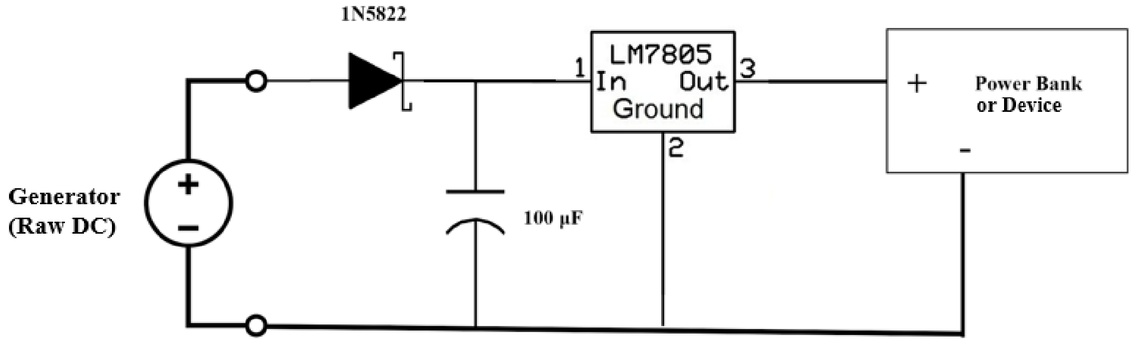


Figure C1: Power circuit schematic.

Appendix D: Cost Analysis

Final Parts List and Cost for Prototype

Part #	Name	Qty	Cost Each With Shipping	Cost total for Production	Source
100	Motor/Generator	2	16	32	Amazon
101	Spindle Wheel	1	3.51	3.51	McMaster Carr
102	Spindle Wheel Shaft	1	4.11	4.11	McMaster Carr
103	Clip Attachment Shaft	1	5.97	5.97	McMaster Carr
104	M5 Lock Washer	10	0.03	0.30	McMaster Carr
105	M3 Screw	2	0.04	0.08	McMaster Carr
106	Wheel Attachment Arm	2	`0.95	1.9	McMaster Carr

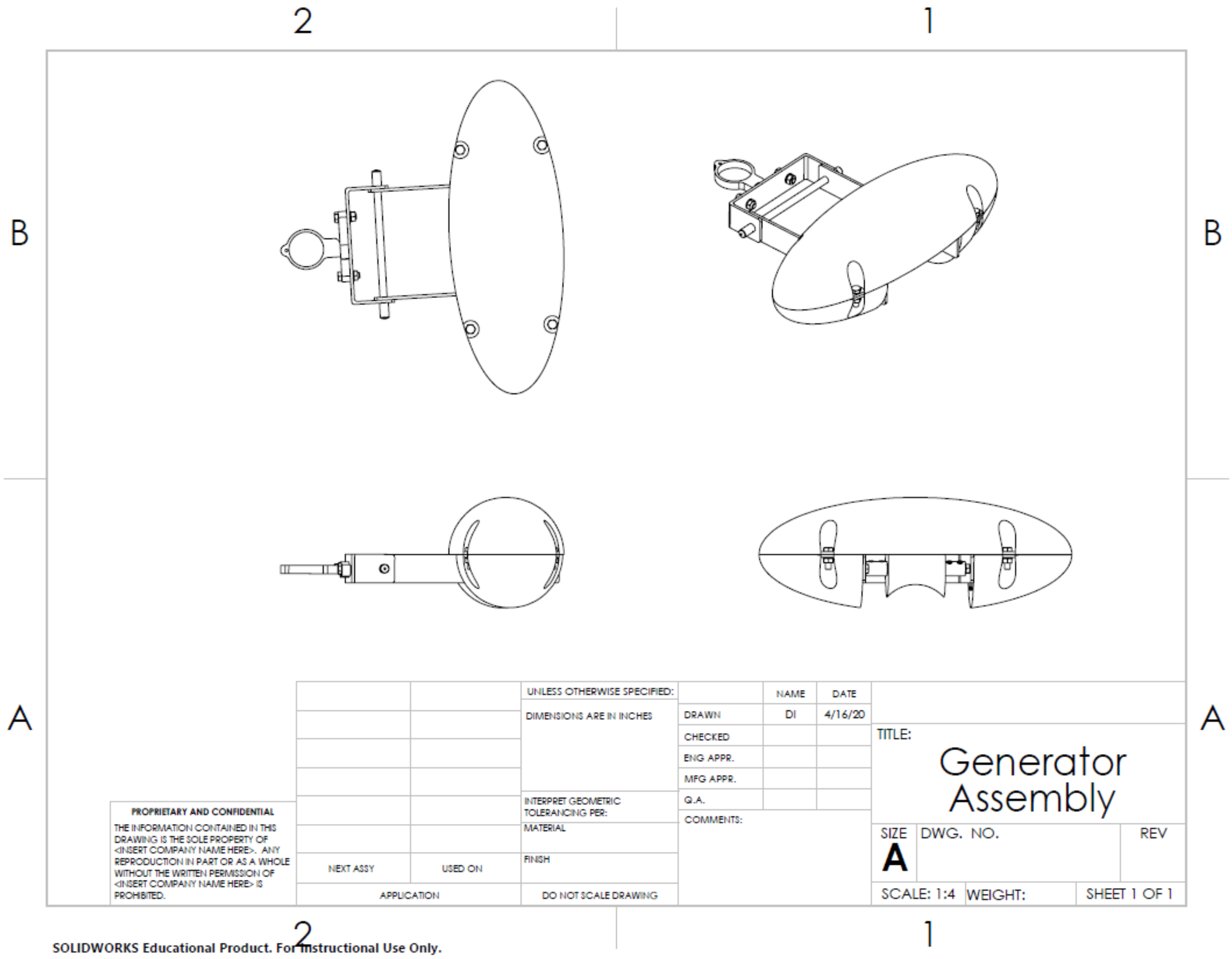
107	Bike Clip Mount	1			Same part as 108
108	Bike Clip Ring	1	8.44	8.44	Amazon
109	Clip Bracket	1	0.95	0.95	McMaster Carr
110	M5 Nut	10	0.02	0.2	McMaster Carr
111	M5 Bolt	10	0.4	4	McMaster Carr
112	Shaft Coupler	2	9.8	19.6	McMaster Carr
113	End Cap	2	0.04	0.08	McMaster Carr
114	Generator Cover Top	1	27.98	27.98	3D Printed MAE Lab
115	Generator Cover Bottom	2	0	0	3D Printed Alderman MakerSpace
201	Phone Mount	1	15	15	Amazon
202	Power Bank	1	20	20	Amazon
301	Schottky Diode, 1N5822	1	0.81	0.81	Digikey
302	L78S05CV High Current Voltage Regulator	1	1.01	1.01	Amazon
303	100uF Capacitor, 50V	1	0.86	0.86	Digikey
401	Wire, 18 gauge (10ft)	1	1.81	1.81	McMaster Carr
402	Electronics Board	1	1.96	1.96	McMaster Carr
	Total Cost:			146.66	

Parts List for Mass Production

Part #	Name	Qty	Cost Each With Shipping	Cost total for Production	Source
100	Motor/Generator	2	12	24	Amazon
101	Spindle Wheel	1	3.51	3.51	McMaster Carr
102	Spindle Wheel Shaft	1	4.11	4.11	McMaster Carr
103	Clip Attachment Shaft	1	5.97	5.97	McMaster Carr
104	M5 Lock Washer	10	0.03	0.30	McMaster Carr
105	M3 Screw	2	0.04	0.08	McMaster Carr
106	Wheel Attachment Arm	2	`0.95	1.9	McMaster Carr
107	Bike Clip Mount	1			Same part as 108
108	Bike Clip Ring	1	8.44	8.44	Amazon
109	Clip Bracket	1	0.95	0.95	McMaster Carr
110	M5 Nut	10	0.02	0.2	McMaster Carr
111	M5 Bolt	10	0.4	4	McMaster Carr
112	Shaft Coupler	2	4.9	9.8	McMaster Carr
113	End Cap	2	0.04	0.08	McMaster Carr
114	Generator Cover Top	1	2.67	2.67	Injection Molded
115	Generator Cover Bottom	2	0.94	1.88	Injection Molded
301	Schottky Diode, 1N5822	1	0.81	0.81	Digikey
302	L78S05CV High Current Voltage Regulator	1	1.01	1.01	Amazon

303	100uF Capacitor, 50V	1	0.86	0.86	Digikey
401	Wire, 18 gauge (10ft)	1	1.81	1.81	McMaster Carr
402	Electronics Board	1	1.96	1.96	McMaster Carr
	Total Cost:			74.34	
	Optional Add Ons				
201	Phone Mount	1	15	15	Amazon
202	Power Bank	1	20	20	Amazon

Appendix E: Drawing Files



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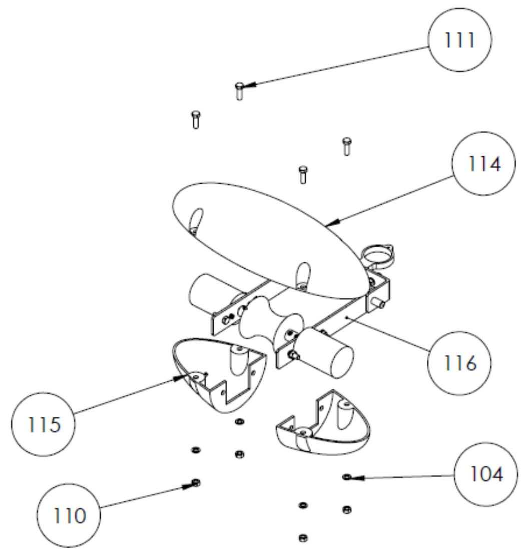
B

Part Number	Part Name	Qty.
104	M5 Lock Washer	4
110	M5 Nut	4
111	M5 Bolt	4
114	Generator Cover	1
115	Generator Cover Bottom	2
116	Generator Subassembly	1



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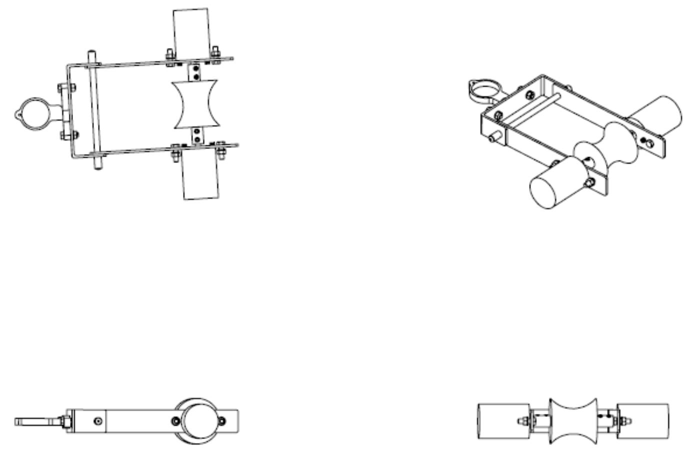

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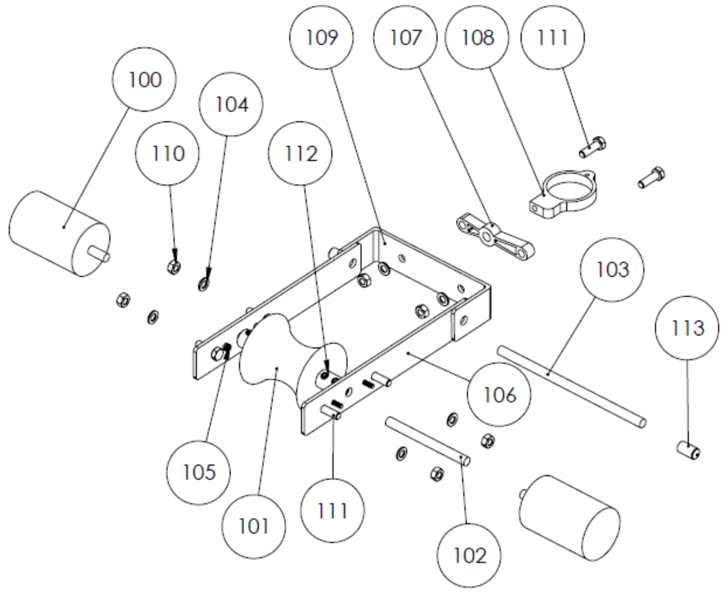
Part Number	Part Name	Qty.
100	Motor/Generator	2
101	Spindle Wheel	1
102	Spindle Wheel Shaft	1
103	Clip Attachment Shaft	1
104	M5 Lock Washer	6
105	M3 Screw	4
106	Wheel Attachment Arm	2
107	Bike Clip Mount	1
108	Bike Clip Ring	1
109	Clip Bracket	1
110	M5 Nut	6
111	M5 Screw	6
112	Shaft Coupler	2
113	End Cap	2



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MFG APPR.		
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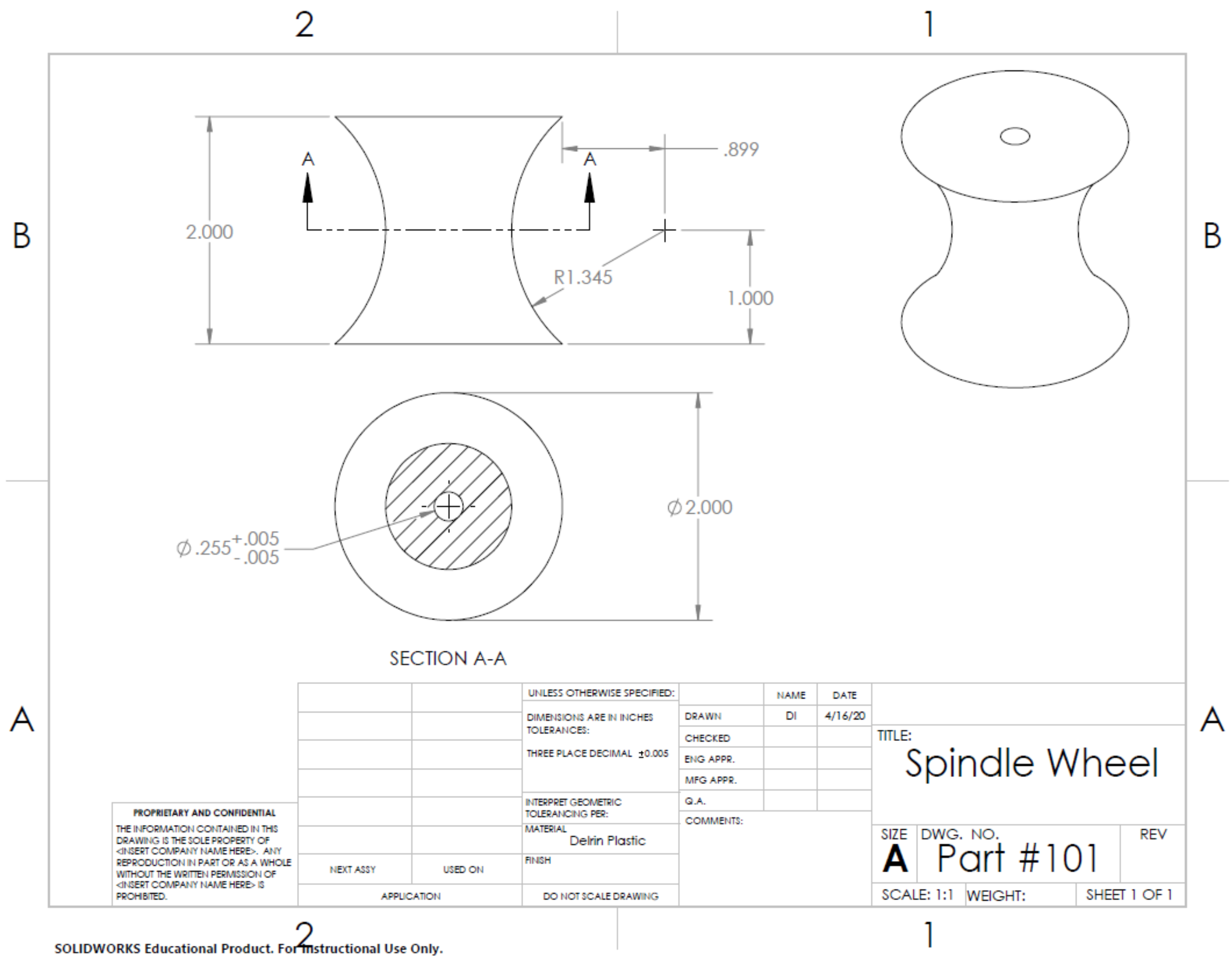
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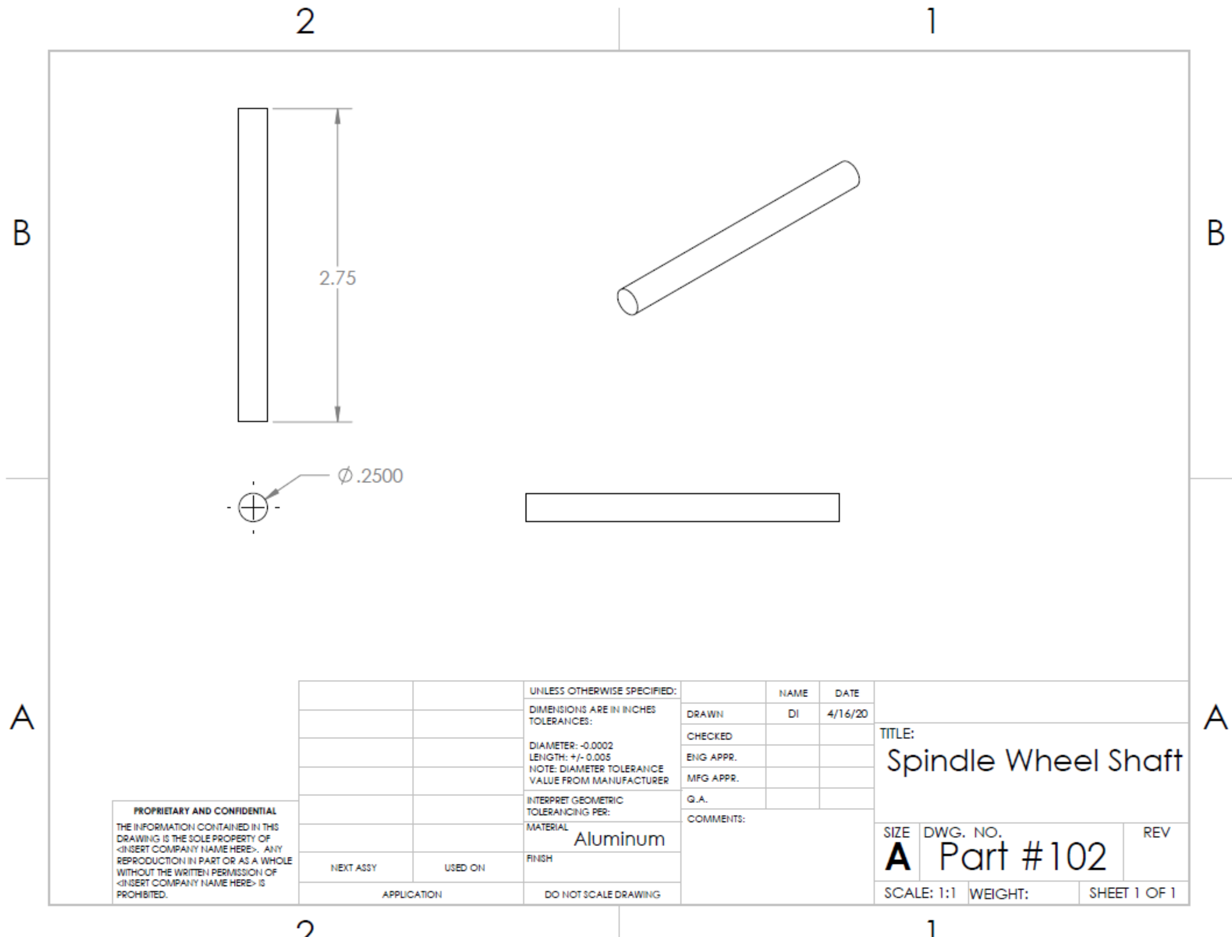

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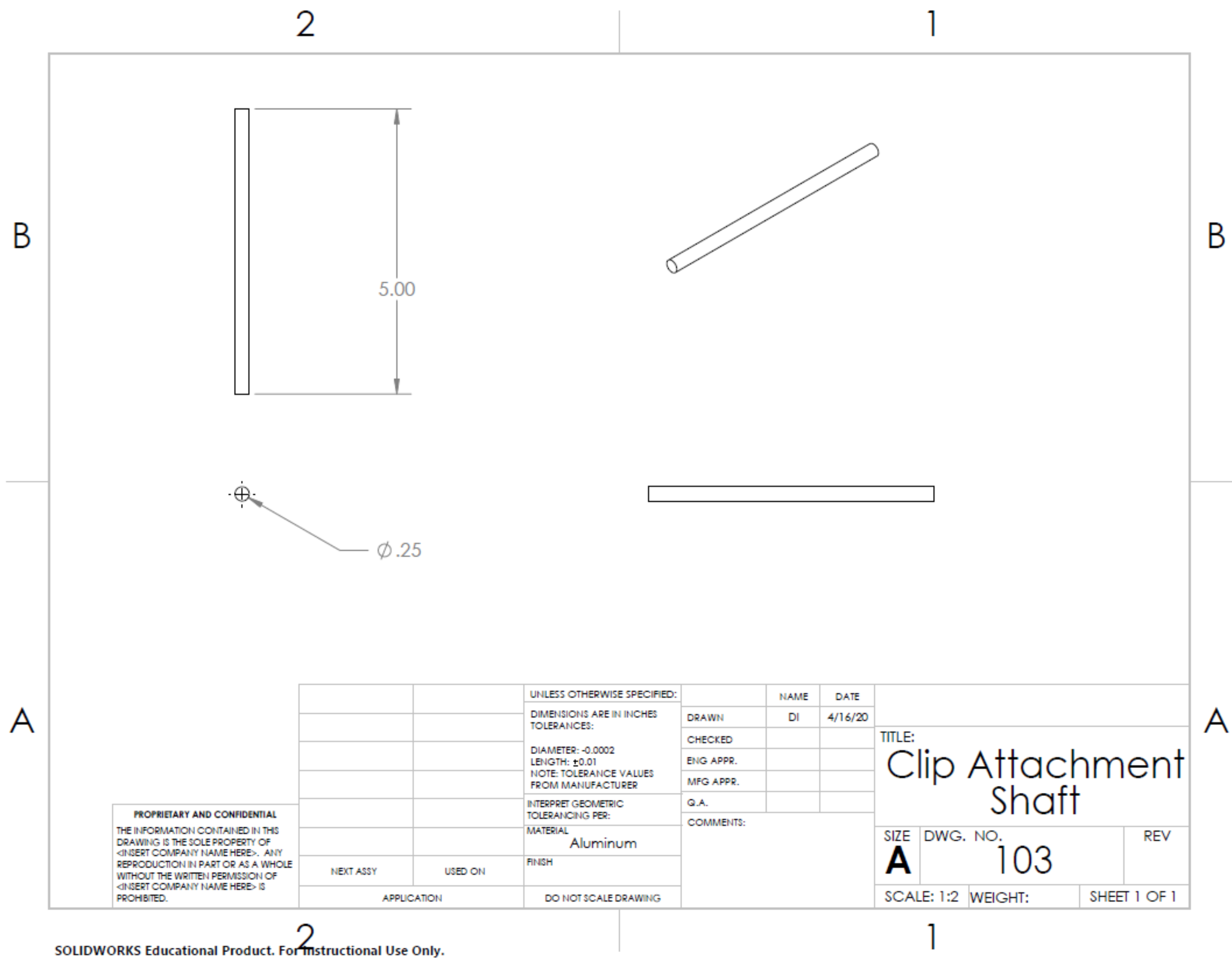
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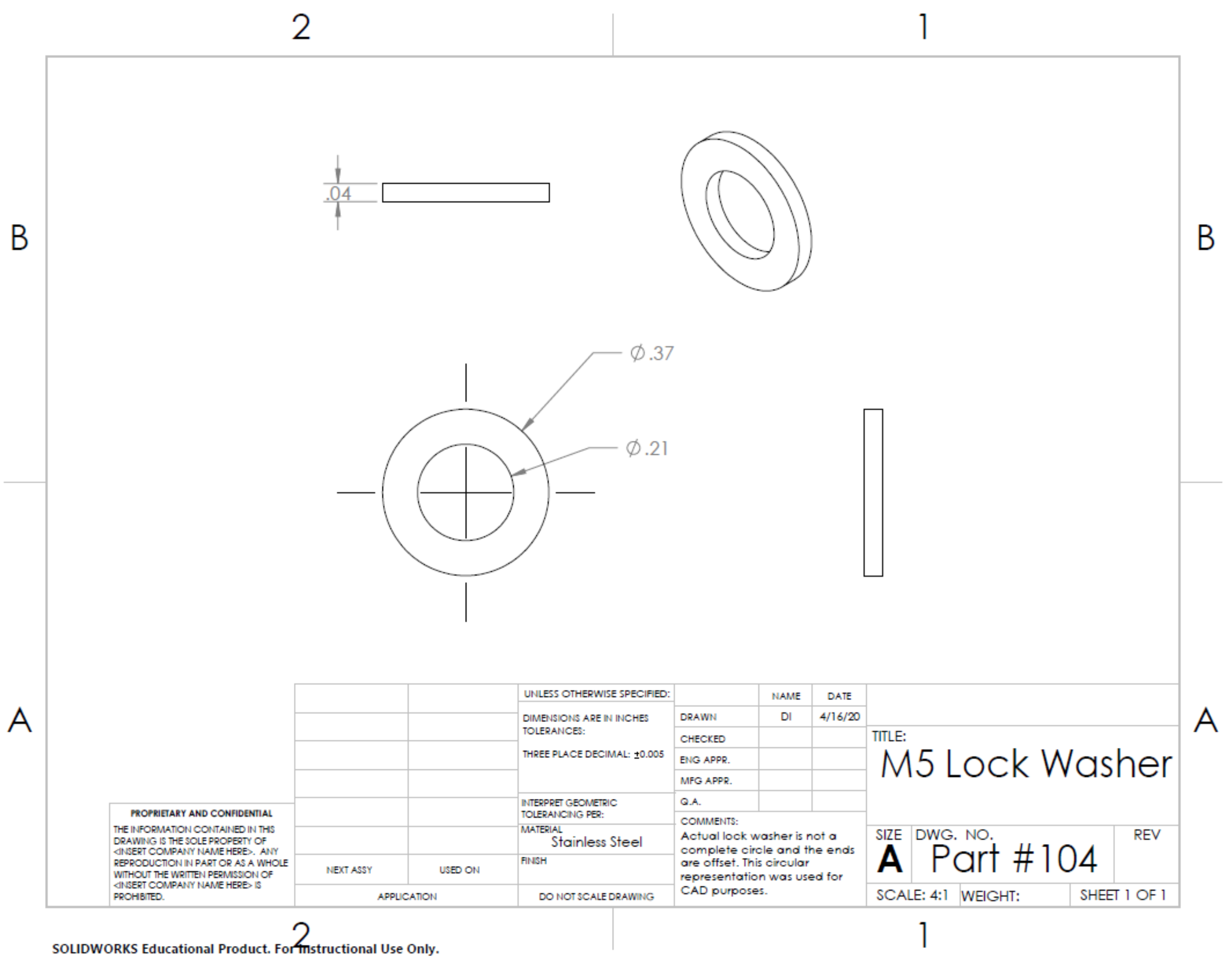
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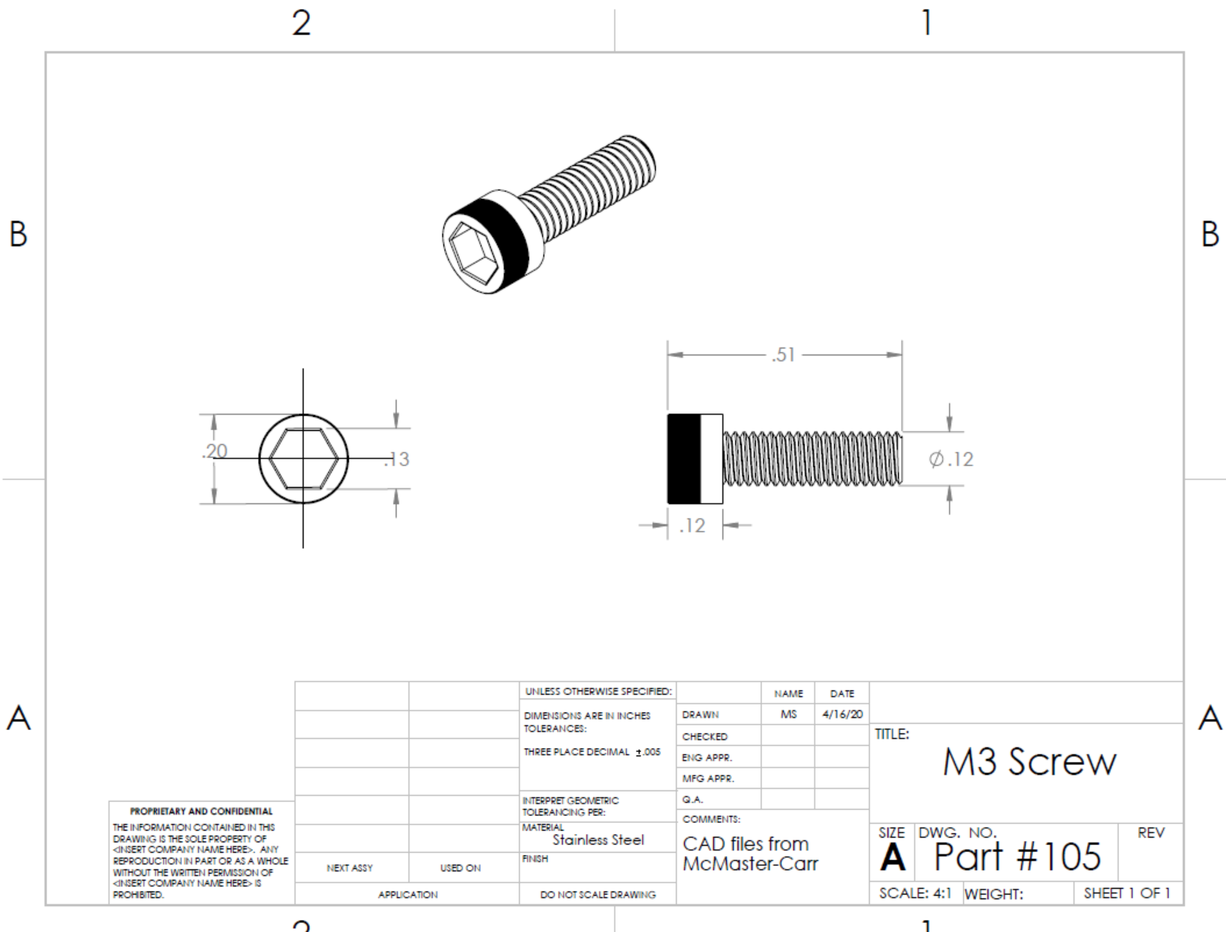
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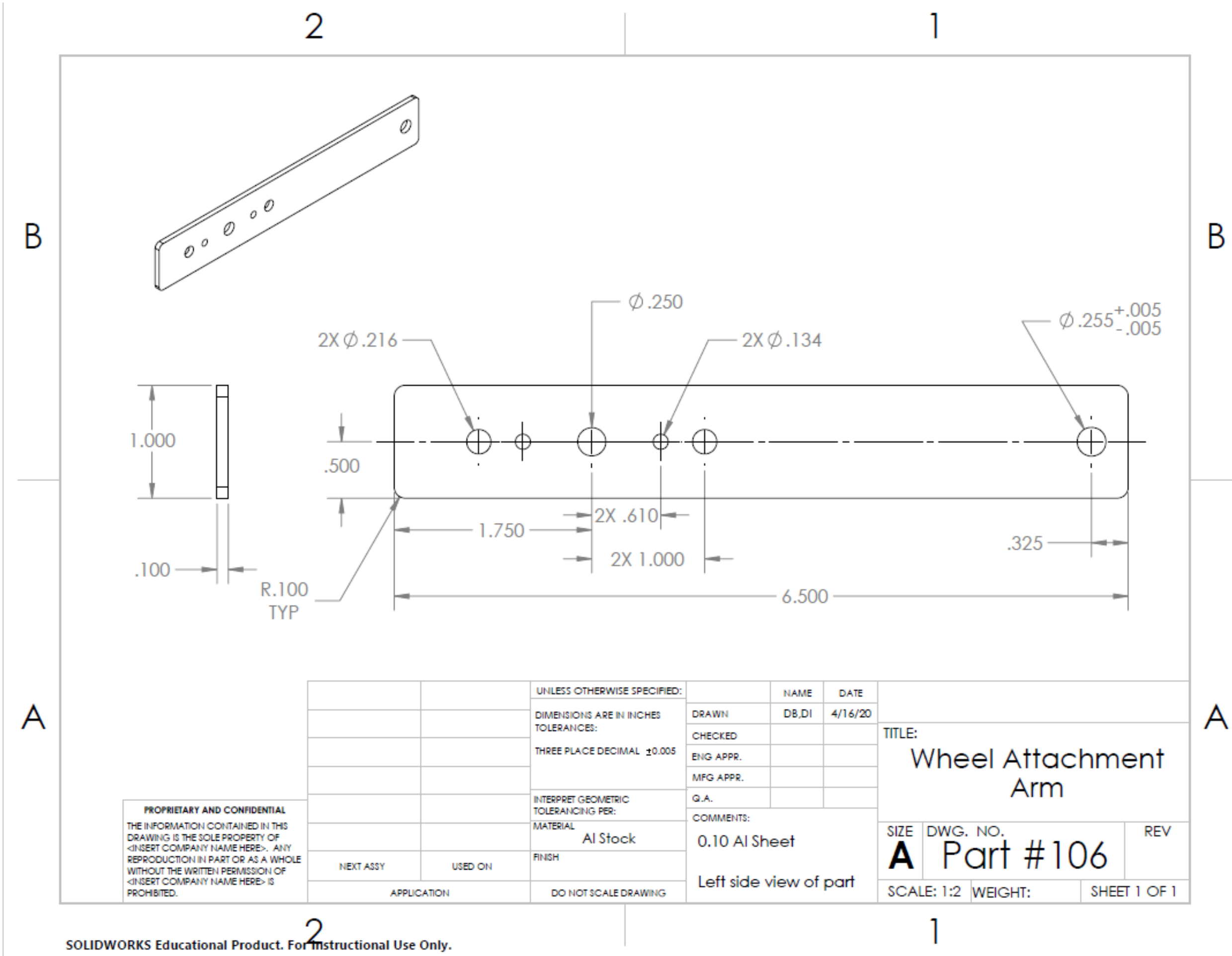
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Left side view of part
TITLE:
Wheel Attachment Arm
SIZE
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DWG. NO.
Part #106
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
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PROPRIETARY AND CONFIDENTIAL
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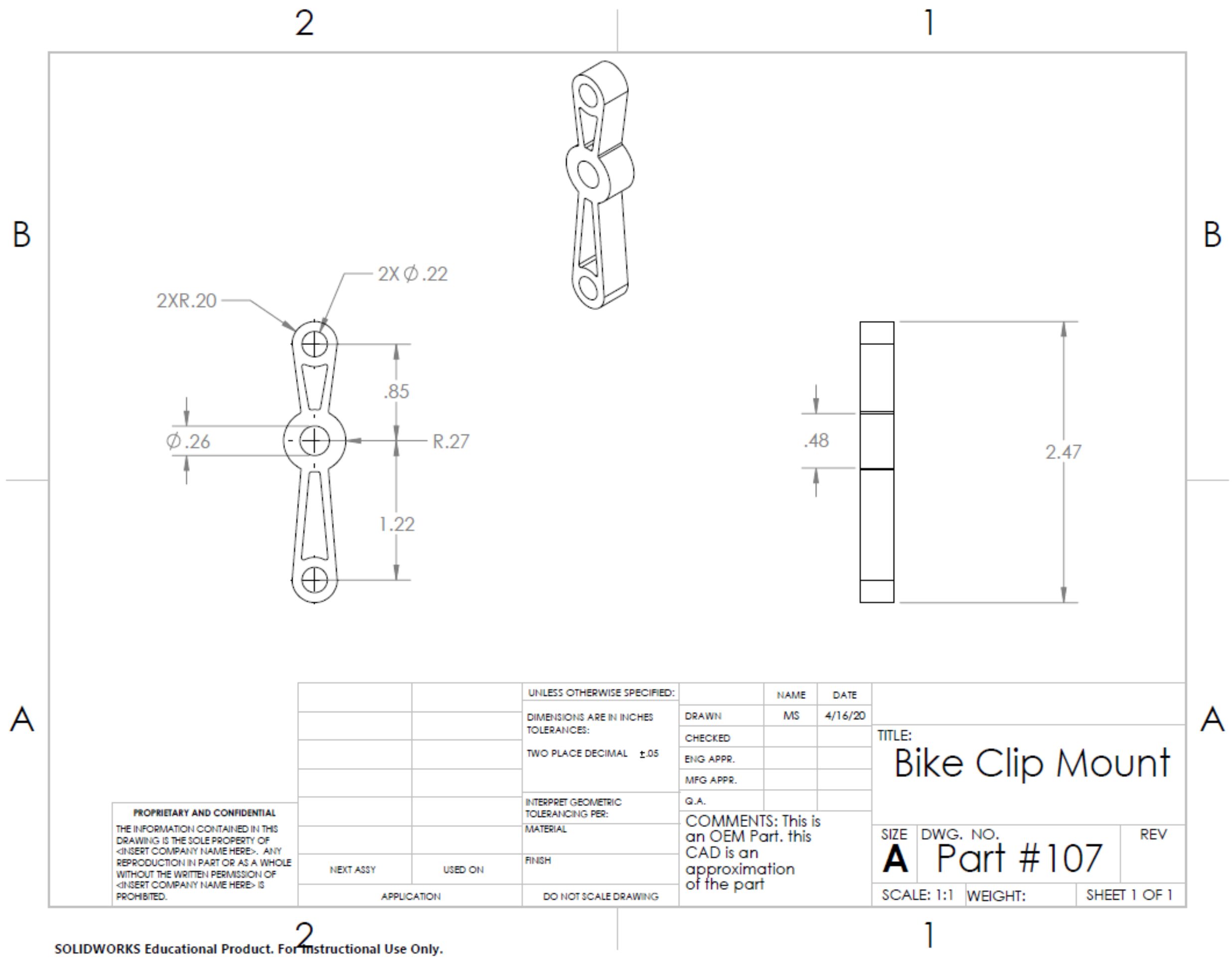
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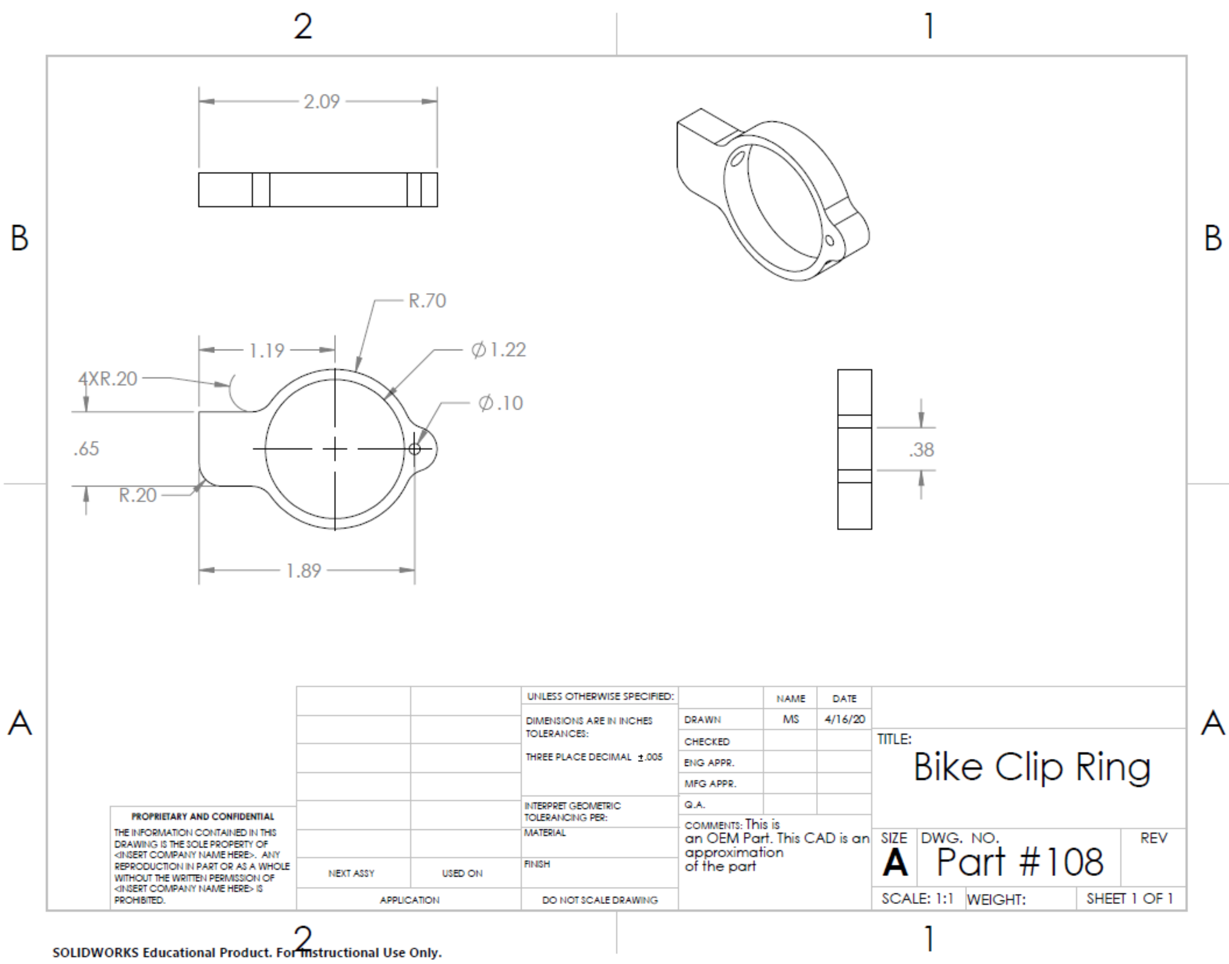
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DIMENSIONS ARE IN INCHES
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NEXT ASSY
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APPLICATION
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NAME
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MS
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MFG APPR.
Q.A.
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Bike Clip Ring
SIZE
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DWG. NO.
Part #108
REV
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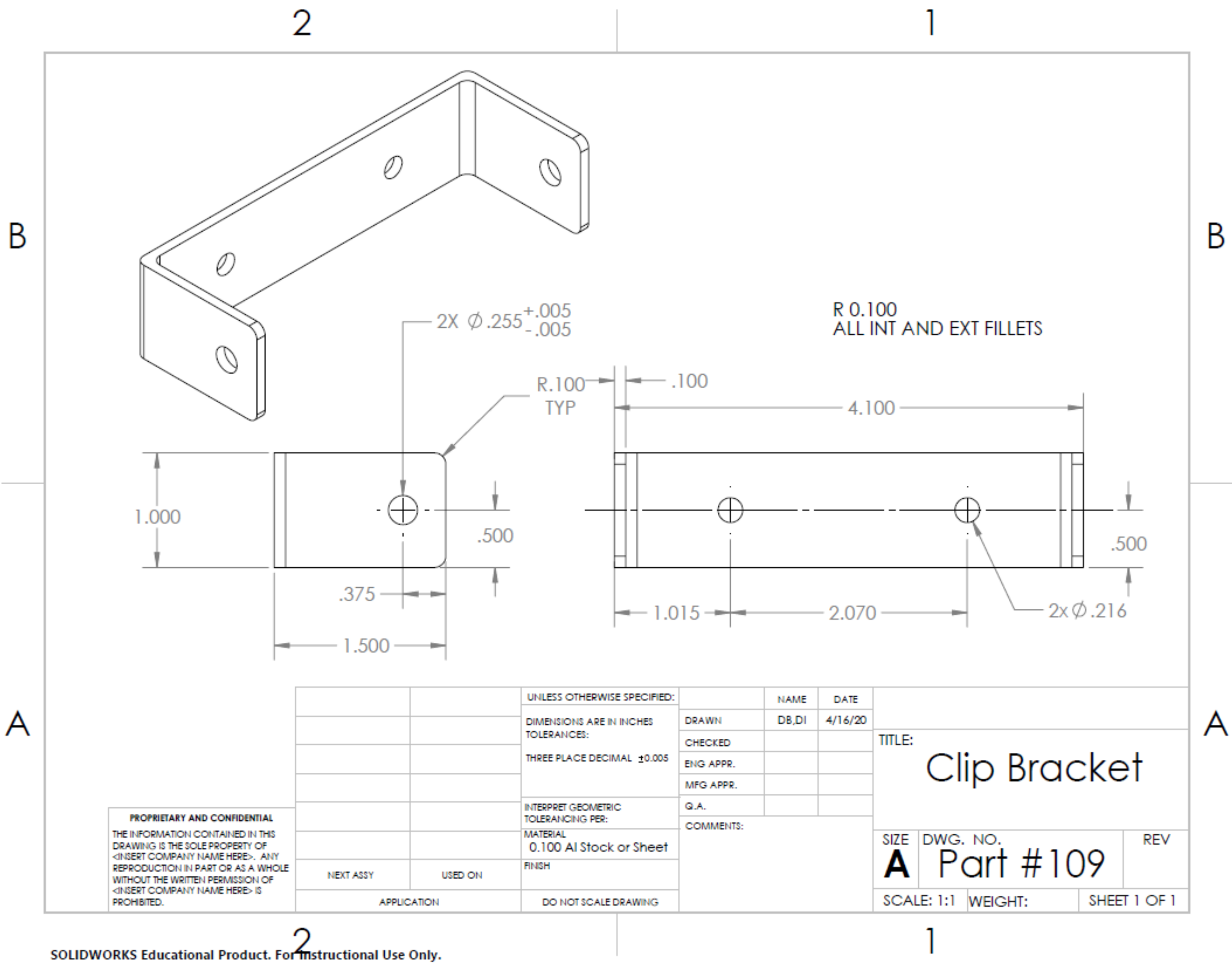
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
0.100 Al Stock or Sheet
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
DB,DI
4/16/20
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Clip Bracket
SIZE
A
DWG. NO.
Part #109
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
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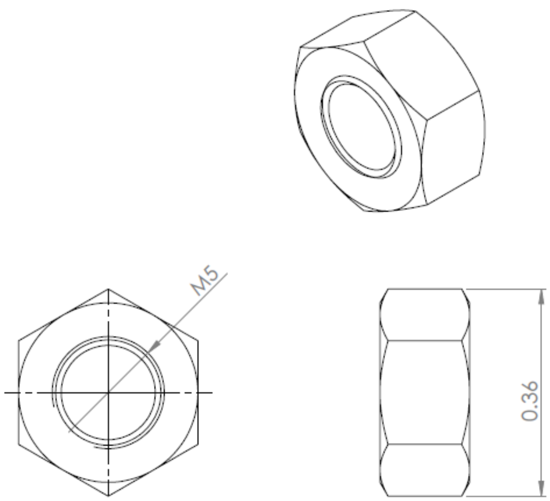

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE		
		DIMENSIONS ARE IN INCHES TOLERANCES:	DRAWN	DI	4/16/20	TITLE: M5 Nut	
		THREE PLACE DECIMAL ±0.005	CHECKED				
			ENG APPR.				
			MFG APPR.				
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.				
		MATERIAL Steel	COMMENTS:			SIZE A	DWG. NO. Part #110 / REV
NEXT ASSY	USED ON	FINISH					
APPLICATION		DO NOT SCALE DRAWING				SCALE: 5:1 / WEIGHT:	SHEET 1 OF 1

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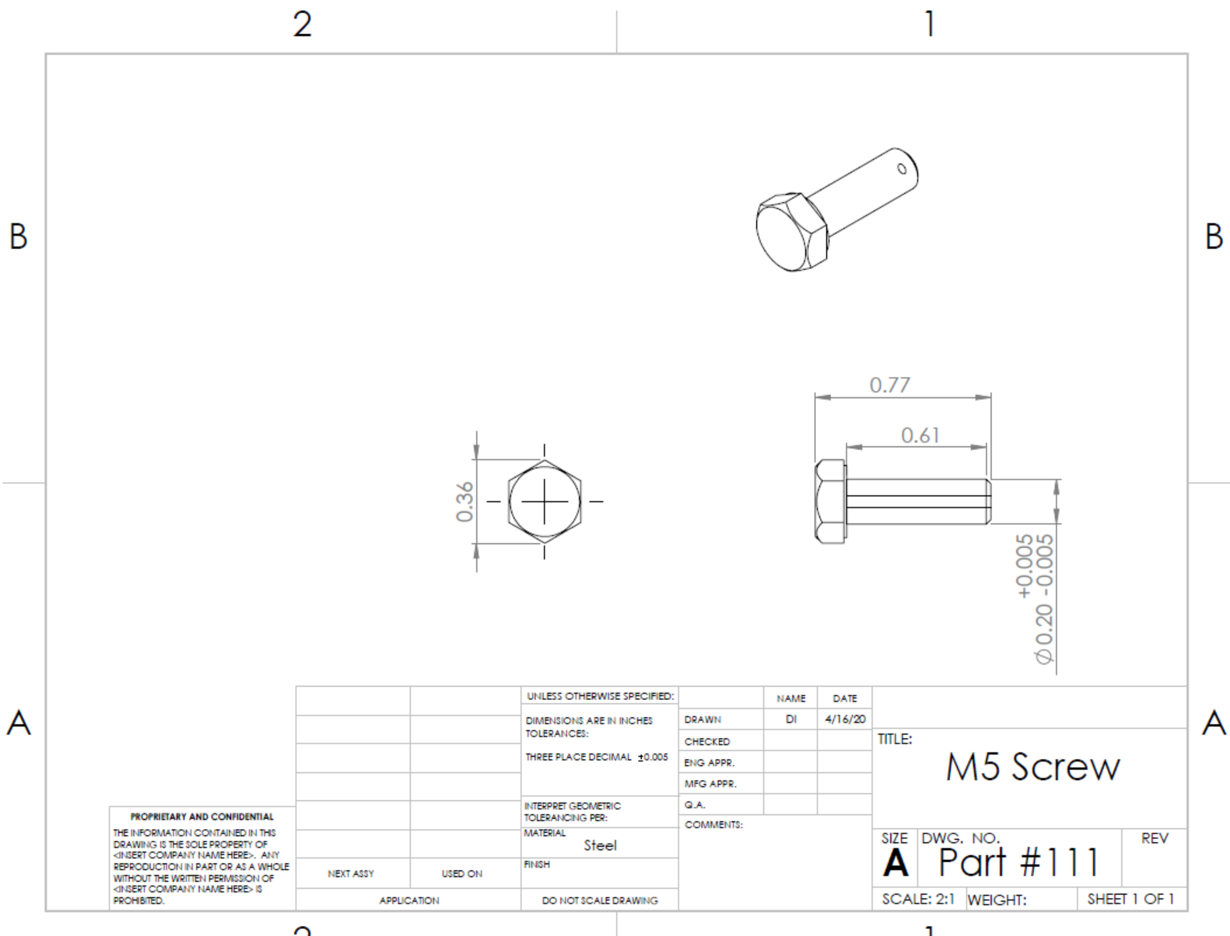
2
1
B
A
0.77
0.61
0.36
⌀0.20 +0.005 -0.005
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
DI
4/16/20
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
M5 Screw
SIZE
A
DWG. NO.
Part #111
REV
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1
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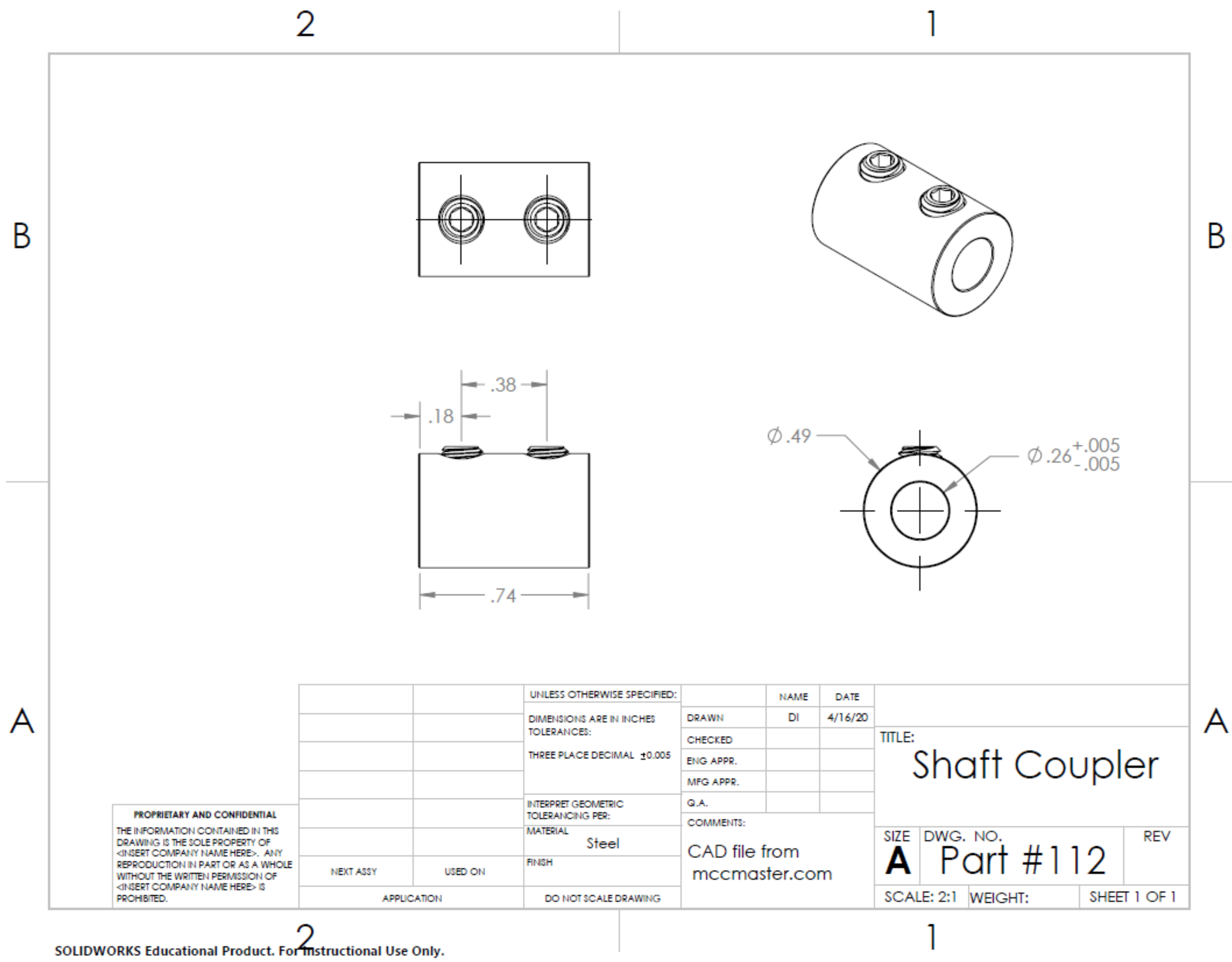

2
1
B
A
.38
.18
.74
∅.49
∅.26 +.005 -.005
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
DI
4/16/20
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
CAD file from mccmaster.com
TITLE:
Shaft Coupler
SIZE
A
DWG. NO.
Part #112
REV
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
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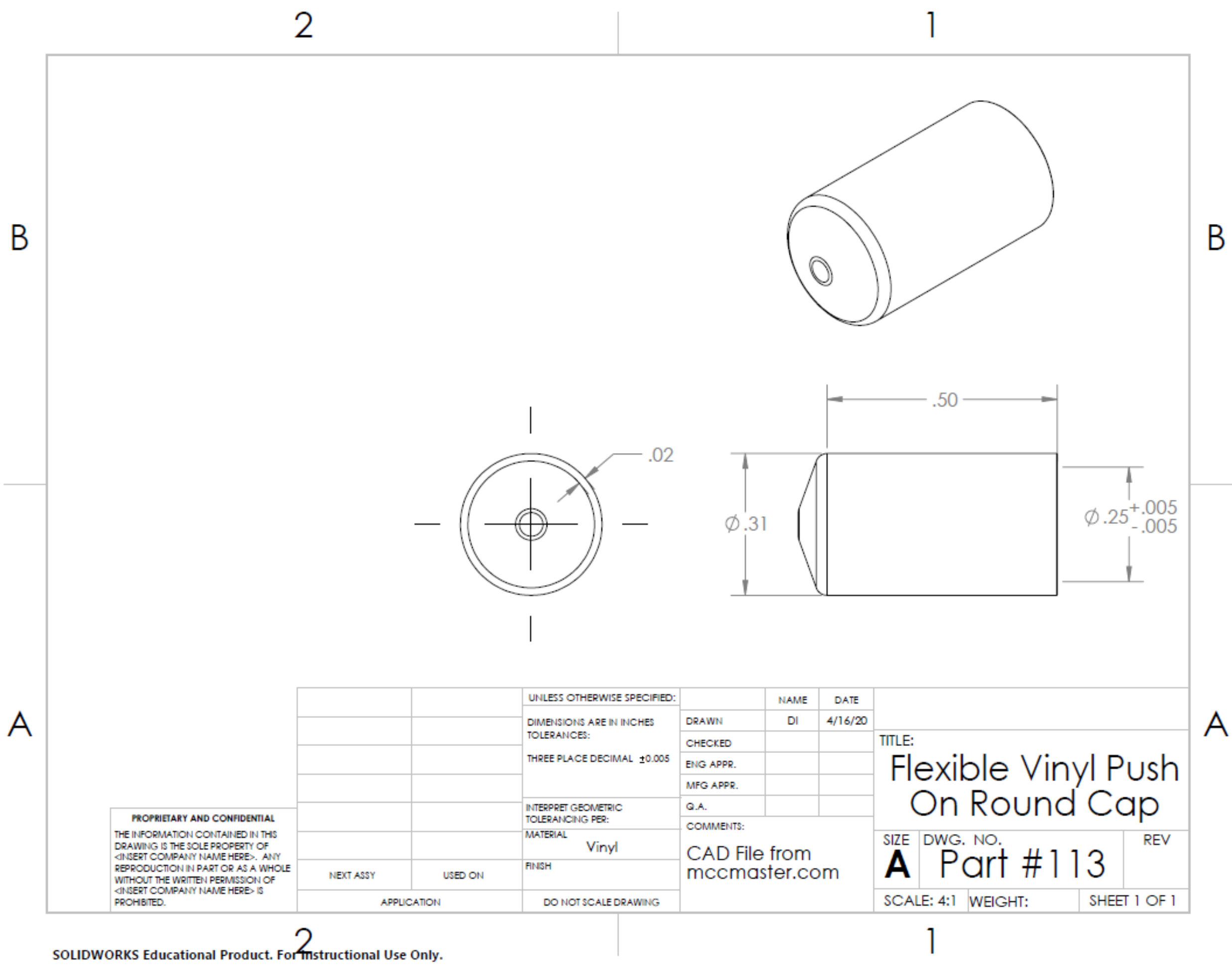
.50
.02
Ø.31
Ø.25 +.005 -.005
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Vinyl
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
DI
4/16/20
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
CAD File from mccmaster.com
TITLE:
Flexible Vinyl Push On Round Cap
SIZE
A
DWG. NO.
Part #113
REV
SCALE: 4:1
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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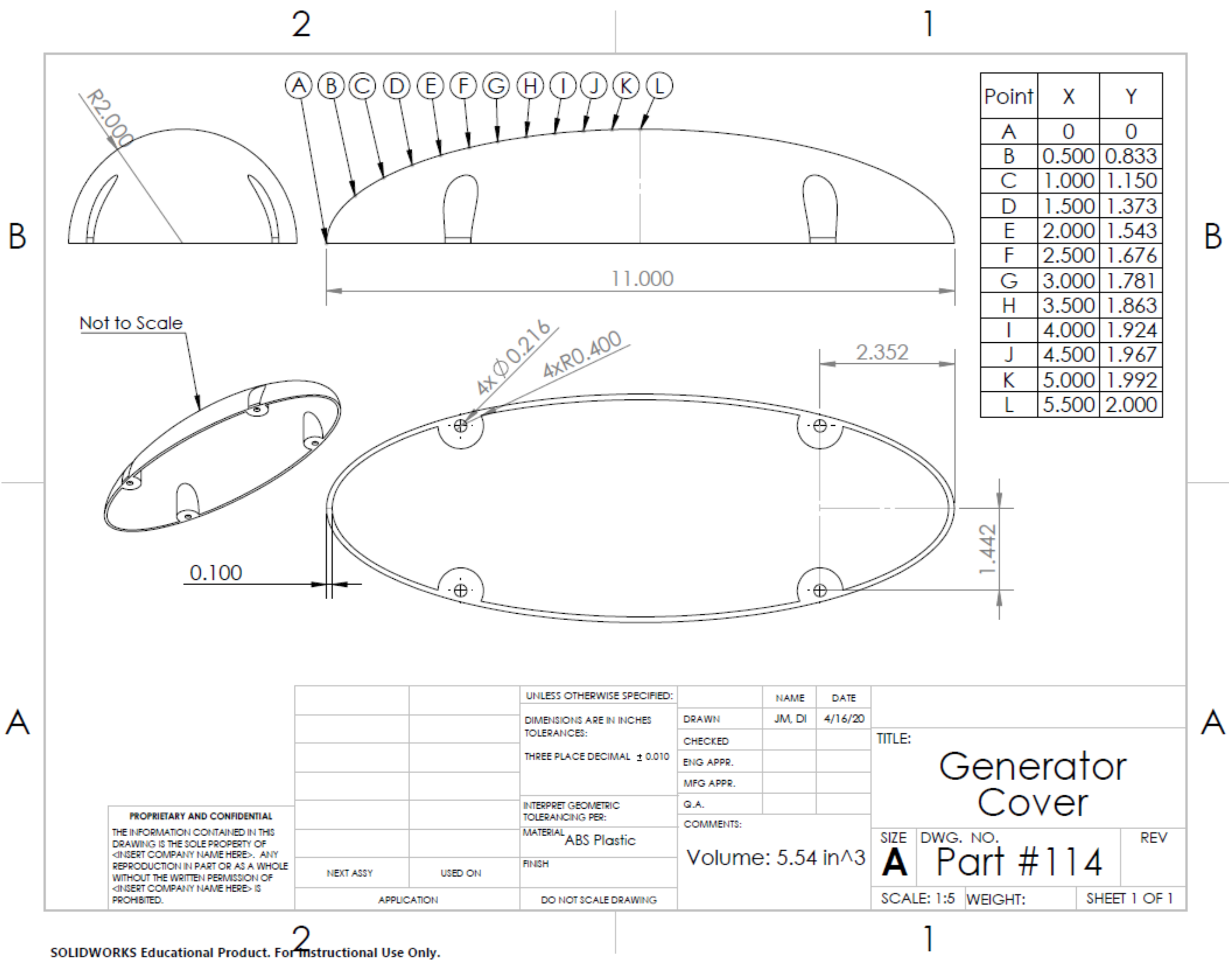
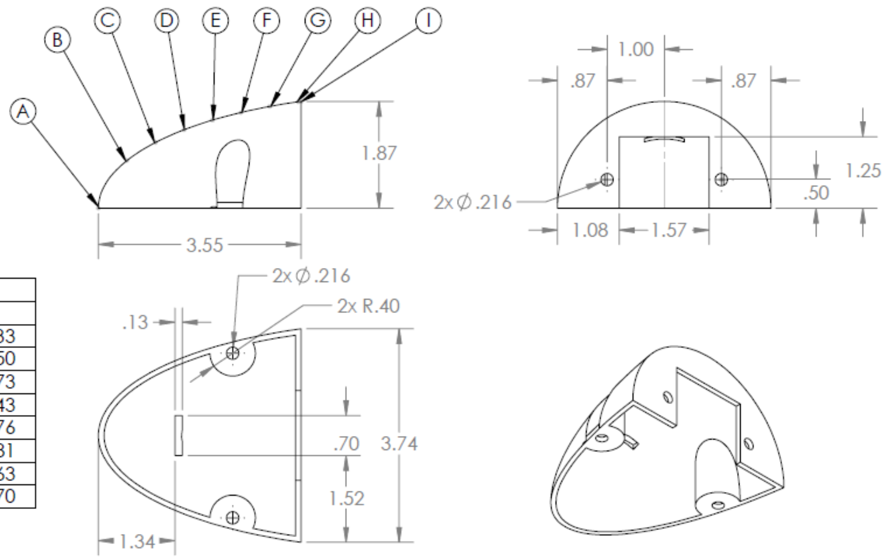


Point	X	Y
A	0	0
B	0.500	0.833
C	1.000	1.150
D	1.500	1.373
E	2.000	1.543
F	2.500	1.676
G	3.000	1.781
H	3.500	1.863
I	4.000	1.924
J	4.500	1.967
K	5.000	1.992
L	5.500	2.000



Point	X	Y
A	0	0
B	0.50	0.833
C	1.00	1.150
D	1.50	1.373
E	2.00	1.543
F	2.50	1.676
G	3.00	1.781
H	3.50	1.863
I	3.55	1.870

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
THREE PLACE DECIMAL: ±0.010
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL ABS Plastic
FINISH

	NAME	DATE
DRAWN	DI	4/16/20
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
Volume: 1.88 in^3

TITLE:
Generator Cover Bottom

SIZE A DWG. NO. Part #115 REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

NEXT ASSY USED ON
APPLICATION
DO NOT SCALE DRAWING