Ultimate Beach Cart

Watson Capstone Project No. WCP52

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Executive Summary

The Ultimate Beach Cart was created so that one person can transport much more waterfront gear to the waterfront than he or she can carry. Some beachgoers will take

more than they can carry and struggle to maintain everything all the way to the waterfront. Others will take a more comfortable amount of waterfront equipment with them and end up making two or three trips back to the car. In order to triumph these inconveniences, we created a device so the user will exert little to no force in order to move up to 200 pounds of waterfront gear to the beach. Some of the features in our design that will help us achieve this goal include an electric drive system and treads instead of back wheels so our beach cart can effectively traverse all types of terrain. Some features that allows our design to be easily portable include an attachment to a standard hitch and a collapsible handle so the design is more compact during transportation. Some other bonus features that set our design apart from the rest include a steerable handle, a solar panel that powers two USB ports, and a rechargeable battery.

The major mechanical components of the design include the treads, the frame, and the handle. The frame is a standard cargo carrier that weighs 26 pounds. This cargo carrier is able to be hitched onto the most common Class III and IV hitches with it's 2 inch receiver. The cargo carrier can also support 500 pounds without failure. The tread design consists of belts and pulleys in order to avoid unnecessary design complications associated with a chain and sprocket tread system. The final design consists of two belt driven pulleys with a tensioning mechanism that provides adequate track tension. The biggest obstacles this design presented were determining the parts needed to attach the treads to the carrier and the necessary tensioning. When the cart is in the retracted position on the trailer hitch, the beach cart treads must withstand the vibrational effects of the vehicle transporting it such that the resonance will not cause the belt to detach. The handle is very similar to that of a pallet jack. In the design of the Ultimate Beach Cart, the steering handle and the front wheel axle were attached as one piece and were run through two plates which were placed externally in front of the frame. This combats tipping and allows for a large steering radius. The handle also collapses so that the cart can be easily attached to a hitch and transported.

At this point in the project we have developed a fully functioning prototype that we have tested and confirmed meets all of the requirements except for the maximum weight requirement. This design is very structurally sound with the minimum factor of safety being 10.1 and occurring on the handle extension rod when subject to a 50 lb pulling force in the case of the battery runs out of charge.

In the very near future, we plan to lower the cost of the tread design, optimize the overall weight with different materials for the design, possibly design the solar panel to charge the beach cart battery as well as the device being charged, and brainstorm more innovative features that will make our beach cart the most desirable on the market.

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1. Problem Definition

1.1 Problem Scope

The beach has always been a destination for friends and family across the world for ages. The crashing waves, cool breeze, and hot sand has enticed many and deterred few. Over the years beach going activities have evolved drastically. What used to be naps on the beach and the occasional dip in the water has turned into beach volleyball tournaments, bonfires, and beach parties full of delicious food and drink. Instead of just a towel, people need to bring wood for a fire, balls, speakers, an umbrella, a cooler with food and drinks, beach chairs and more to the beach. Often it is not possible for people to carry all of these items in one trip down to the beach from their car. This tends to be a nuisance for avid beach goers who wish there was a way to easily transport all of their belongings to the beach and back without having to make multiple trips.

1.2 Technical Review

The method for transporting beach belongings between one's car to the beach has yet to be perfected. For most young people, the best method is to catch hold of as much as possible in your two arms and attempt to carry everything down to the beach. While struggling to make sure you don't drop anything, you must also worry about tripping over your own two feet or other obstacles that were obstructed by your view. Older people are more sensible and will only carry a reasonable amount of items to the beach at one time. More often than not, this causes them to make two or three trips back and forth. The best to solution to everyone's problem would be some type of beach cart that could transport all of one's belongings together at once. Many types of beach carts are currently available, but each one contains its own setbacks. These setbacks include a weak frame that cannot handle much weight, wheels that cannot traverse efficiently in the sand, no drive system, and no way to charge one's portable device, among many others.

1.3 Design Requirements

This project aims to design an electronically driven beach cart that can traverse sand, gravel, and grass. The beach cart should easily attach to a standard hitch and weigh less than 70 lbs. The design must also be able to support a load of 200 lbs. These requirements are imperative to the basic structure of the Ultimate Beach Cart. In addition, the beach cart shall be powered by an electric drive system so that it can be operated by a single user. The battery that powers all of this should be rechargeable. The cart will also consist of a collapsible handlebar that allows the user to steer the cart and condense the overall design for transport. It is also important that the beach cart be able to travel in reverse. Because of the easy access to sunlight that the beach provides, solar panels should be attached to the beach cart to allow for charging of common USB port devices (0.5 to 2.1 Amps). All of these design requirements serve to promote the Ultimate Beach Cart as a convenient option for the user. [See Appendix B: Project Requirements for a complete list of requirements.]

2. Design Description

2.1 Overview

The Ultimate Beach Cart was created so that one person can transport much more waterfront gear to the waterfront than he or she can carry. There are many products on the market that already help people with this issue so it was our job to improve upon the current beach cart designs. One major problem with commonly used beach carts is the user must exert an undesirable amount of force on the beach carts when pulling them through sand. Also, the more gear and equipment they need to bring to the waterfront, the harder it is for the user to move their beach cart. With our design, the user will exert little to no force on the beach cart in order to move it. Also, the amount of waterfront gear loaded onto the beach cart will not affect the amount of force provided by the user. This was accomplished by powering our beach cart with an electric drive system. The other aspects of our design that differ from the common beach carts used today are the easy attachment to a standard hitch, a collapsible handle for storage, a solar panel that powers two USB ports, and treads instead of back wheels so our beach cart can effectively traverse all types of terrain.

One day, a group of people decide they want to go to the beach. They get all of their bags, a cooler, and other waterfront gear loaded up in their car. As long as the car has a standard hitch on the back, they will be able to use the Ultimate Beach Cart. Two people would lift the beach cart and slide the attachment right into the standard hitch on the back of the car. The wing nut should be adjusted so the handle of the cart is collapsed rather than in the upright position. The cart is suspended by the hitch and is now ready for transport.

When the group arrives at the beach, the first step is to detach the Ultimate Beach Cart from the trailer hitch on the back of the car. Once that is completed, the wing nut can be adjusted to put the collapsible handle in the upright position. After that, all the waterfront gear can be loaded onto the Ultimate Beach Cart. Once the cart is fully loaded, someone can take the key and turn on the UBC. Once the cart is powered on, the user can then turn the throttle on the handle and begin walking their waterfront supplies to the beach. The UBC is steerable making it easy for the user to avoid the many beach obstacles and reach the ideal location. Once the ideal location is met, you can turn off the UBC and all of the waterfront gear you need will be with you. The solar panel works independently from the electric drive system so charging a cell phone or using the USB ports for anything will work just fine when the UBC is powered off. When it is time to leave the beach, power the UBC with the key and start walking the waterfront supplies back to the car. When the user makes it back to the car, unload the waterfront gear from the UBC back into the car. The user must then loosen the wing nut to collapse the handle and then reattach the UBC to the trailer hitch on the back of the car. Once attached, the group is ready to head home after an ultimate beach experience.

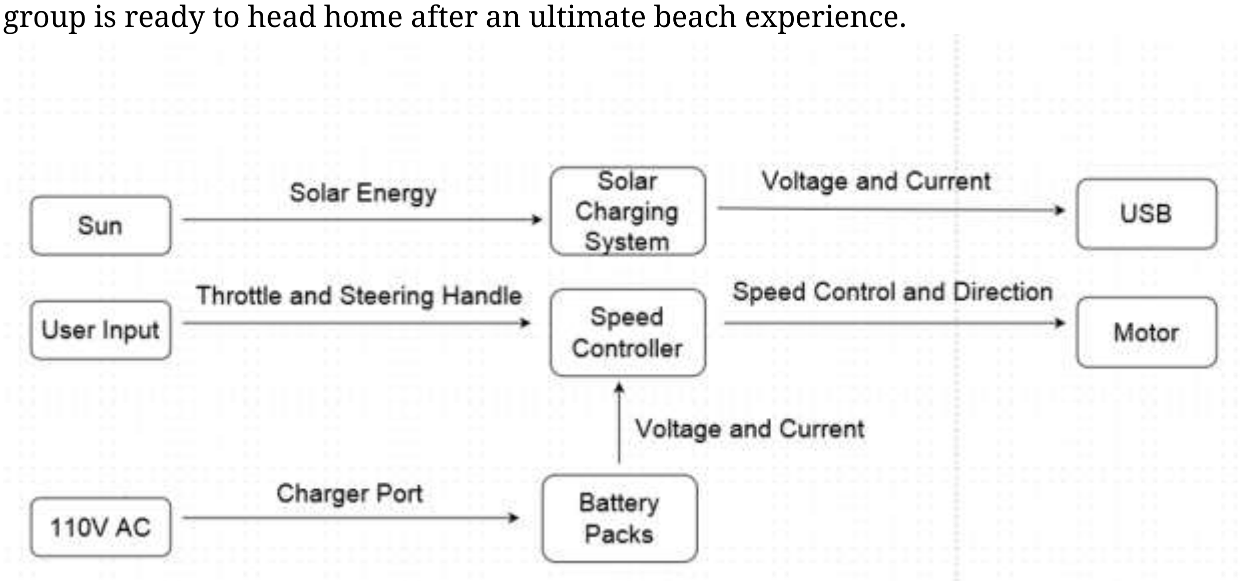


Figure 1: Operational Context Diagram

2.2 Detailed Description

The Ultimate Beach Cart is a multidisciplinary engineering project which requires both mechanical as well as electrical design. For the cart, critical mechanical components which required much attention to detail in the design as well as analysis were the treads, the frame, as well as the handle. As for the critical electrical components, the parts which required much detail in the design were the electromotive system and the solar charging system.

2.2.1 Frame

One of the biggest key design factors in the beach cart was to make it as user-friendly as possible. As such, the original requirement of making the beach cart completely collapsible was modified in such a way where a trailer hitch was utilized. In the original design, a frame was constructed with grooved edges such that a large cooler would be able to fit snugly inside. However, after several design iterations, it was decided that it was feasible to just use a cargo carrier as the main frame of the beach cart and to use one that was compatible with a 2 inch receiver, as it is used by most Class III or Class IV hitches. For this design a 26 lbf cargo carrier was used and whilst on the trailer hitch, the frame can support up to 500 lbf without fail.

2.2.2 Tread Design

The tread system is vital to our design because this is what our electric motor powers in order to move the Ultimate Beach Cart. We decided to go with a tread system instead of wheels because it would be able to traverse rocky, sandy terrain much better than wheels. Treads will never dig into the sand and get stuck like wheels would because it has much more surface area. Our original tread design consisted of a timing belt and three pulleys. Our plan was to use the electric motor to drive the tread axle shaft which would attach to the top pulley of a triangular scissor linkage configuration. The two bottom pulleys would revolve around idler shafts in this design. In order to keep the pulleys in place each of the two bottom pulleys have a link which connects them to the top belt-driven pulley. A spring is then placed running across and connecting the links from both bottom pulleys. The spring constant value (*k*)for this spring is very important to the design. The heavier the load is on the UBC, the more tension there will be in the spring. Consequently, the more tension there is in the spring, the less likely the belt will slide off the pulleys or lose its traction to the pulleys.

2.2.3 Handle and Front Wheel Axle Design

In this design, the handle and the front wheel axle was assembled in such a way that they were attached. Initially, the front of the beach cart was supported merely by a single pole in the center and two handle bars were attached to the axle connecting the wheels. This design stuck for the first couple of design iterations until several unforeseen contingencies during the time emerged from traditional engineering judgement. The biggest problem with the steering mechanism was the lack of balance at the front of the cart. With the weight of the beach cart along with the applied load of 200 lbf as specified by the initial requirements, the front of the beach cart would put too much stress on just the one pole which is attached to the wheels as well as increasing the potential to tip on either side. To resolve this problem, another design was used, which took inspiration from the steering mechanisms of standard pallet jacks. In the design of the beach cart, the steering handle and the front wheel axle were attached as one piece and was run through two plates which were placed externally in front of the frame as shown in figure 3. Such an orientation eliminated the issue of tipping sideways and still allows for mobility for rotation.

Figure 3: Steering mechanism

To further improve mobility and keep the beach cart user friendly, the original proposed requirement of making the entire beach cart collapsible was slightly changed. Perhaps one of the biggest goals of the cart was to be as user-friendly as possible. Thus, the addition of a trailer hitch was applied. However, with the addition of such component, when the cart is mounted, the handle must be either detached or retracted to minimize the amount of loose parts sticking out. This is because if there are loose parts, the vibrational effects of the transporting vehicle may cause the parts to break off. To combat this, the handle and axle assembly consists of Al6061 tubes which are pin connected in the aforementioned orientation to allow for the mechanisms in figure 4 to occur. The mechanisms allow for the axle beam to retract downward and the handles to fold downward as well. For this assembly, the components are able to move due to the use of screws and wing nuts used as pins; tightening the wing nuts would compress the grooved surfaces, which would inhibit rotational mobility. The handle is attached with the use of a collar which is tightened with the similar configuration of screws and wing nuts.

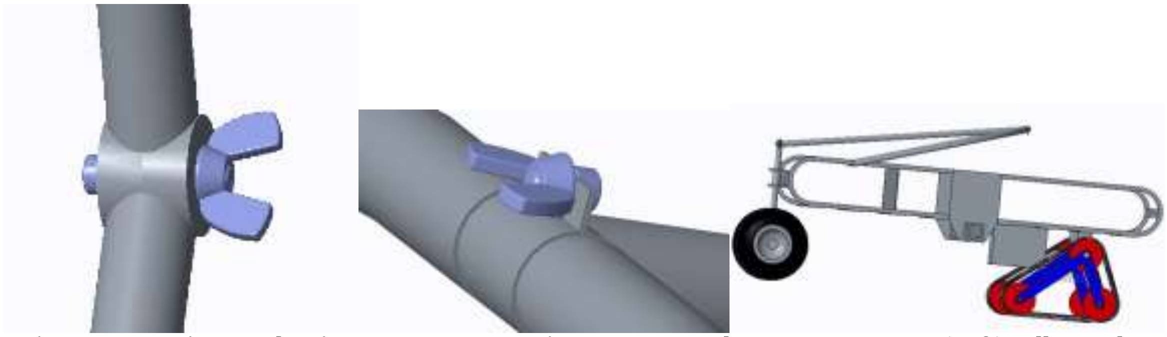


Figure 4: Steering mechanism components. Wing nut are used as components to (Left) collapse the pinned joints for the axle and extension bar and (Right) the collar for the handle. Middle: Right: Beach Cart in retracted position.

2.2.4 Electric Drive System Design

The electric drive system consists of six main parts: battery packs, power switch, battery charger port, speed controller, motor and throttles. The popular commercial motors for electric beach cart are 24V and 36V. After researching, the closest available motor is a 24V, 500W motor which is able to motivate at least 250 pounds of weight. Also according to Motorized Mobility Assistance Device (MMAD) project's calculation, the power for carrying 250 pound is 437W. Hence the 24V, 500W motor is sufficient to meet the load requirement of our project. The battery packs that we chose to use are two 12V lead-acid batteries because of their cheaper cost and higher popularity. They can be recharged by 110-120V AC via battery charger port. Electronic parts are all connected to the speed controller. The initial proposal only required motivating beach cart regardless of direction, but we decided to add directional controls to make the cart more user friendly. As a result, there is a polarity button on the throttle which can control beach cart moving either forward or backward by changing rotating direction of motor. Also, the speed can be varied by twisting throttles according to the need of user. From the system view shown in Figure 5, throttle sends the input signal from user to speed controller and speed controller sends the output signal to motor for the movement.

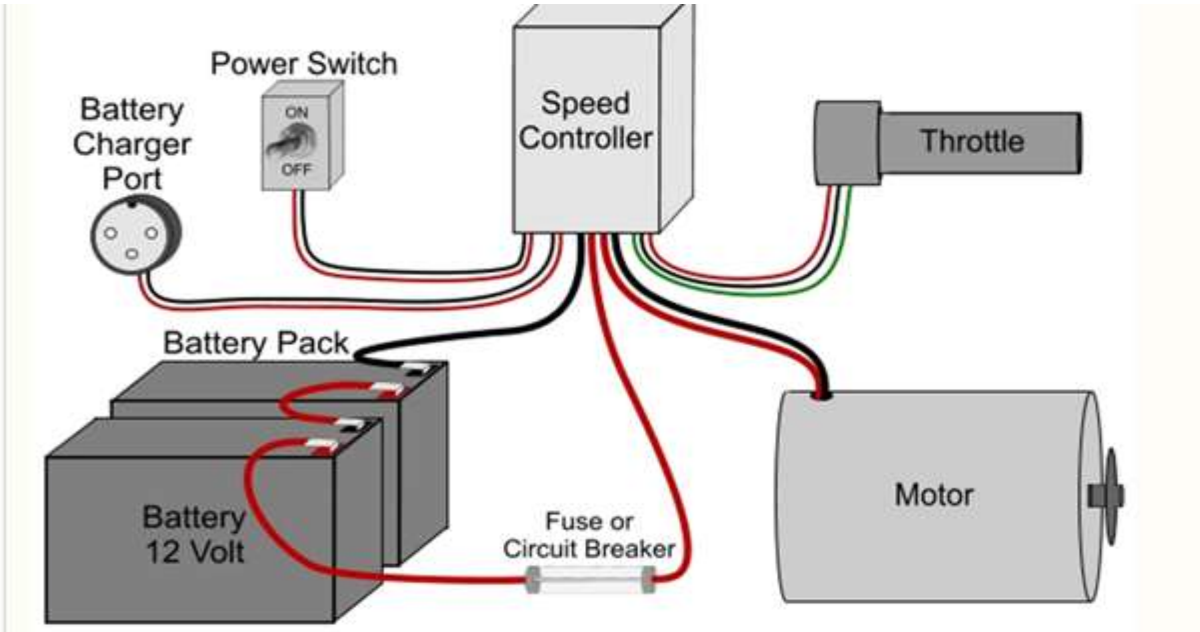


Figure 5: Electric Drive Layout Diagram

2.2.5 Solar Charging System Design

The solar panel, Lithium Polymer battery, charge controller and Buck-Booster converter are included in our solar charging system.

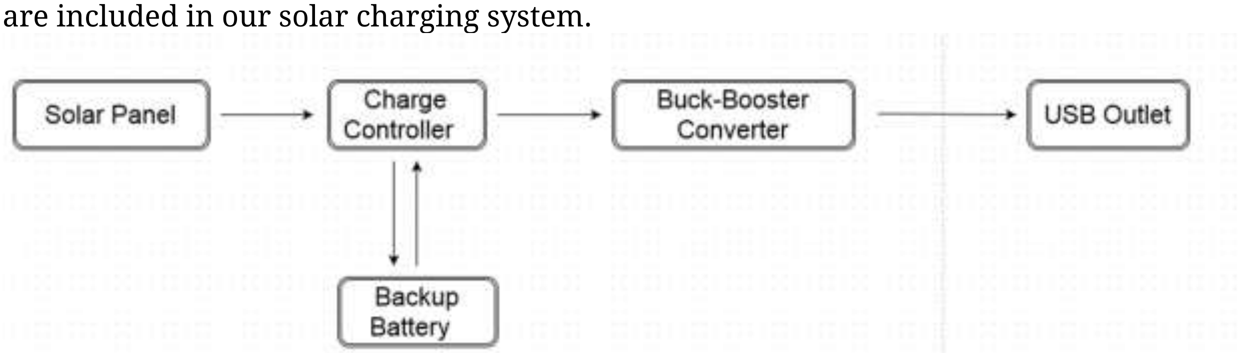


Figure 6: Solar Charging System Block Diagram

The solar panel is selected based on a number of criteria- compatibility, size, cost and availability. Compatibility refers that solar panel can be easily mounted, size refers to the volume of solar panel, cost refers to the cost-effectiveness, and availability refers that solar panel can be easily found for purchase. Also after researching online, we found that there would be a 10%-20% input power lost on the transmission, which means the voltage of solar panel should be slightly higher than output voltage (5V). As a result, a 6V, 2W solar panel is chosen for collecting solar energy, while its maximum current only ups to 333.3mA. In addition, Lithium Polymer battery is considered as backup power supply because the solar panel may not work properly in rainy or cloudy days and at these times Lithium Polymer battery is going to be major power supply powering USB outlet. To manage power sharing of solar panel, backup battery and load, MCP73871 charge controller is a suitable choice meeting our needs in the project.

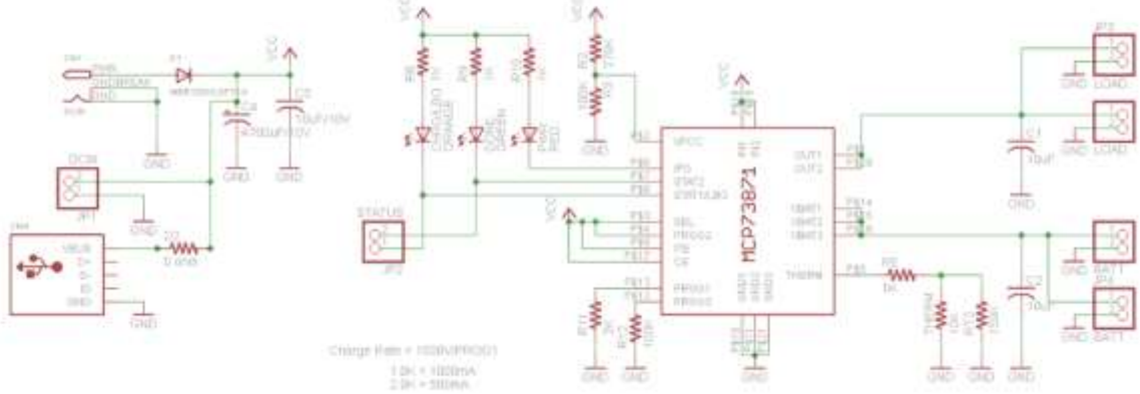


Figure 7: MCP73871 Charge Controller Schematic

As shown in referenced Figure 7, MCP738731 allows input power resource to simultaneously power the system and charge Lithium Polymer battery and automatically obtains power for the system load from a Lithium Polymer battery or an input power resource. Furthermore, this configuration provides adjustable charge rate which can be varied from 50mA up to 1A and constant voltage regulation which can be fixed with four available options: 4.10V, 4.20V, 4.35V or 4.40V. Lastly, by connecting LEDs and resistors into status pins, the charge controller is able to indicate three charge status : red light refers good power supply, green light refers work done, and orange refers charging, which are easily for us to troubleshoot in the test.

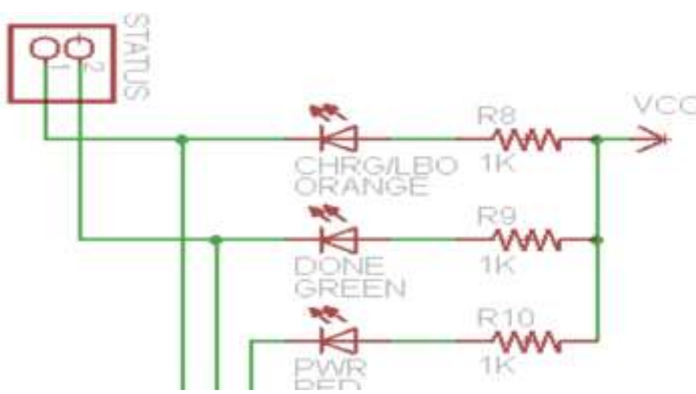


Figure 8: Status Indicators in MCP73871 Charge Controller

While the output voltage of charge controller is at most 4.4V, we may want to boost voltage to steady 5V to meet the input voltage requirement of USB outlet by applying a buck-booster converter.

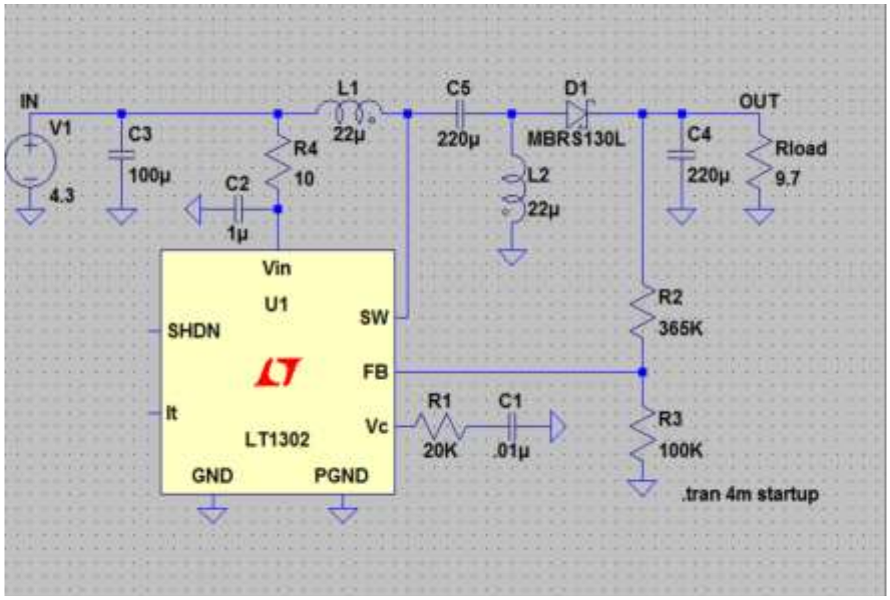


Figure 8: LT3102 Buck-Booster Converter

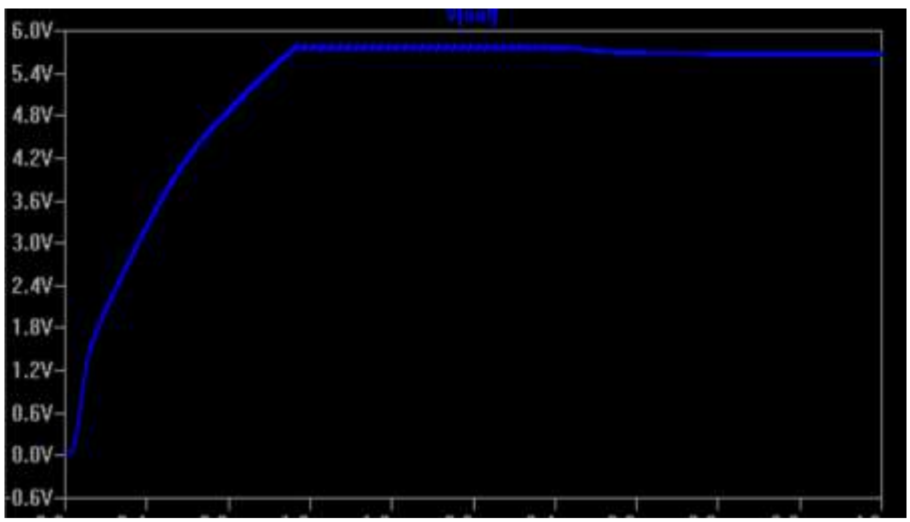


Figure 9: LT3102 Buck-Booster Converter Output Voltage Simulation

From the simulation shown in Figure 9, we can see the output voltage fixed at 5.5V after 1.2ms. With the consideration of internal resistance of the USB cable line and transmission loss, the final output voltage will be around 5V which is suitable for powering a series of electronic devices such as phones, speakers, mp3s and mp4s. Even if the output voltage is a bit higher or lower than 5V, most USB devices tend to hover around 4.75V to 5.25V.

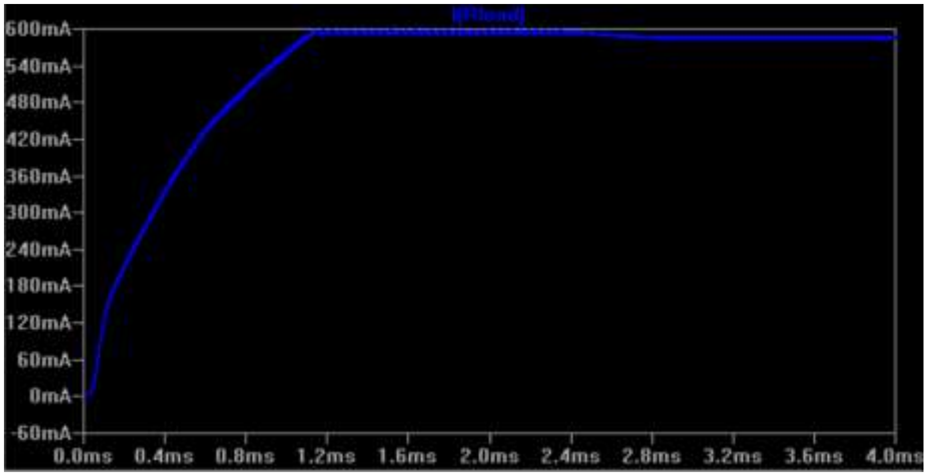


Figure 10: LT3102 Buck-Booster Converter Output Current Simulation

Figure 10 shows simulation the output current fixed at 600mA after 1.2ms. In regular USB 1.0 and 2.0 specifications, a standard downstream port is able to deliver maximum 500 mA current. Considering 10%-20% power loss during transmission, we found that the final output current will be around 500 mA. Although there are plenty of chargers such as iphone charger and car charger that have higher current output, they have higher power ratings than our selected solar panel according to Power equation (P=IV). After searching online, we found that a normal 6V, 6W solar panel costs triple price than a 6V, 2W solar panel. Furthermore, the difference of USB output current only affects charging speed. Hence we still decide to use 6V, 2W solar panel.

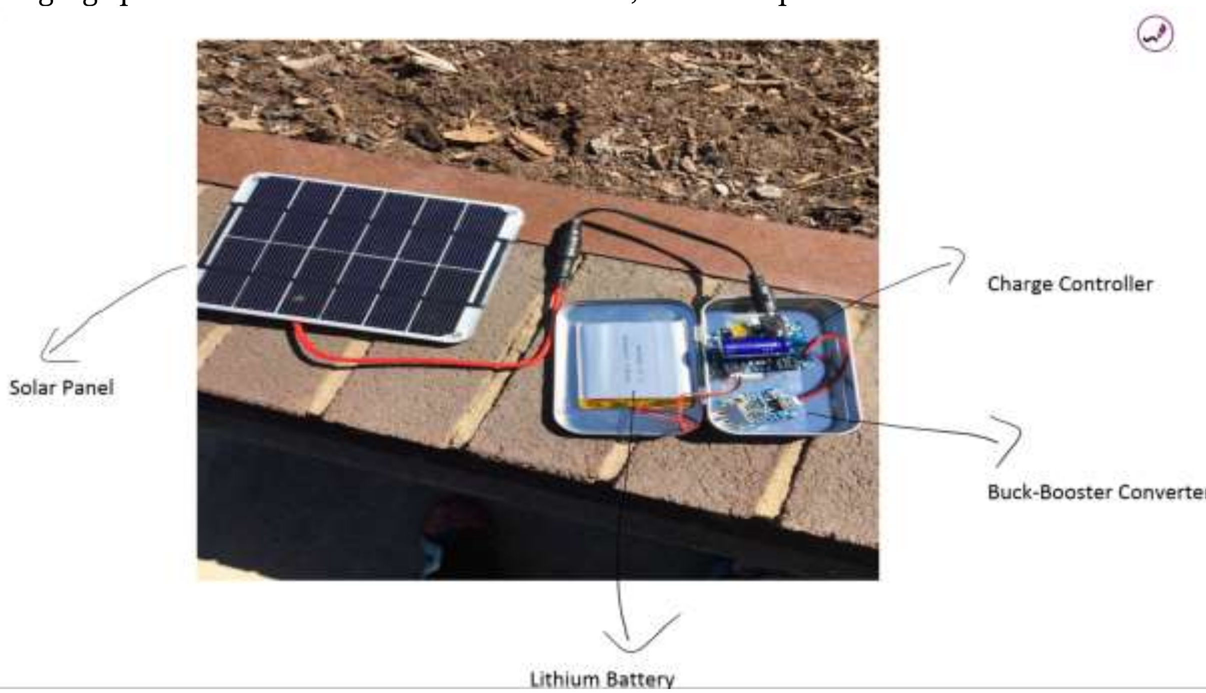


Figure 11: Implementation of Solar Charging System

Figure 11 is the implementation of solar charging system. The solar panel is connected to charge controller with a 1.3 to 2.1 mm adaptor. In order for portable use we decide to put charge controller, buck-booster controller and lithium battery in a tin box; We plan to mount solar panel on the beach cart horizontally to achieve high conversion efficiency. When lithium battery has enough charges, we can disconnect solar panel and the tin box becomes a portable charger, since lithium battery is able to provide power to USB outlet. When lithium battery runs out of charges, we can connect tin box back to solar panel in order for charging inside lithium battery, and solar panel provides power to USB outlet besides charging lithium battery.

2.3 Use

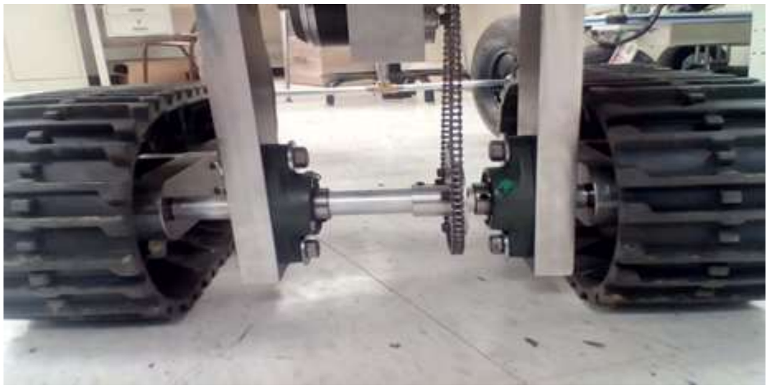
The ultimate beach cart can be operated by all capable users. Very few beach carts have an operable drive system, while no beach carts currently on the market contain a USB charging port for your portable device. The ultimate beach cart will have both the drive system as well as the charging port. The drive system, fully equipped with a reverse function, will be motor operated by a rechargeable battery. The motor will power treads placed at the back of the beach cart, making it easy to traverse on the sand. The charging port will receive power from solar panels placed on the ultimate beach cart so the user can always charge their phone or tablet device while at the beach. To operate the ultimate beach cart one simply needs to turn the throttle on the handle to move forward. To move in reverse you must flip the switch and turn the throttle. The ultimate beach cart will have plenty of space for a cooler, chairs, beach balls and anything else the user wishes to bring to the beach while being strong enough to hold up to 200 lbs.

3. Implementation

When we began to order parts and implement this tread system, we ran into issues due to budget and ordering constraints. We realized that a standard timing belt was not ideal for the sand because they are generally very smooth. We wanted a belt with grooves in it to help the treads grip the sand as much as possible without losing traction. It was at this point that we stumbled upon the snow blower tracks that were used in our design. The track is 4.6 inches wide, 42.6 inches long, and weighed 4.6 pounds. These were ideal for traversing through snow so we knew they would be very effective in sand as well as other terrain. There were sprockets that were pre-made and a perfect fit for the snow blower tracks with 7.56 inch diameter. When we inquired about the sprockets, we asked them if they had them in a smaller diameter in order to apply our 3-sprocket tread design. We talked directly with a manufacturer and they explained that in order for them to customize a sprocket size for us, we would have to order hundreds of sprockets at once. Due to this ordering and budget constraint, we decided to go with the pre-made sprockets which changed our entire design to a 2-sprocket tread system. This meant that we would not be able to implement our scissor linkage and spring strategy to the tread design so we had to think of another way to tension the tracks. Initially our plan was to go back to our original idea to use a thin metal plate to keep the sprockets in place. When we brought this notion to our advisor Professor Zaychik, he explained that in time the track would start losing tension and the distance between sprockets would have to be adjusted after some usage. After further analysis we were able to come up with a tensioning system for the treads. The back of the cart consists of two tread assemblies that are driven by the tread axle shaft. Each tread assembly had tensioners on the outside and inside of the sprockets. We put them on both sides of the tread assembly in order to increase stability and limit the amount of torque that the treads would experience.

The tensioners are made up of a male and female part that were made in the machine shop. The male part rested on the idler shaft and the female part rested on the tread axle shaft. The male part had a threaded rod protruding from it and the female part had a clearance hole for the threaded rod. There were two hex nuts placed on the threaded rod. The first hex nut would be tightened up against the female part to increase the tension of the of the snowblower track. The second hex nut was there to simply lock the first hex nut in place in case vibration attempted to loosen the first hex nut. We also placed 6802 ZZ ball bearings in the tensioners to allow for smooth rotation of the tread axle shaft. Our next plan of attack was to design the tread axle so it could withstand a 200-pound load, fit into the tread sprockets, and drive the tread system without interference. We made the majority of the shaft a 1-inch diameter aluminum shaft and on the ends we pinned two steel shafts with a 0.6-inch diameter. We had a key hole cut into both steel shafts because there were key holes in the tread sprockets that we needed to utilize. The keys were put in to fill the space between the shafts and the sprockets so when the tread axle rotated, the treads would rotate with it. We also made small cuts on the ends of the aluminum shaft so it would only touch the bearings and not rub up against the tensioners when rotating. The last step we took was to machine a flat slightly off-centered from the aluminum section of the tread axle. This was done so we were able to implement our chain and sprocket motor. We had a motor mount machined and screwed right onto the bottom of the cargo carrier. We also had a collar machined for the drive sprocket so we could screw that directly into the flat part of the tread axle. After our drive shaft was created, we just needed a way to attach the entire tread system to the bottom of the cargo carrier. We also had to make sure that this connection would provide the perfect amount of tension to the chain for our chain and sprocket motor. This is when we went to the machine shop and got two pillow block holders machined. These were made from aluminum and had threaded holes at the top so they could be screwed right onto the bottom of the cargo carrier. We placed some washers in between the bottom of the carrier and the pillow block holders in order to get the perfect amount of tension on our motor chain. We purchased the pillow blocks because they gave our drive shaft some degree of freedom to rotate within them. This lowered the amount of radial force exerted on our tread axle which decreased its likelihood to snap. The tread system was very effective in driving the Ultimate Beach Cart and was necessary in order to meet our requirements. The only difficulty with our tread system was because it was so powerful and strong, it added some extra weight to our design that we didn’t account for. By making the tread system resilient enough to meet our requirements, it contributed to our inability to meet our weight requirement. With a higher budget we would be able to attach the tread system to the Ultimate Beach Cart using lighter materials.



The front axle handle configuration was made from aluminum scrap metal. The axle is pinned six inches in from either end to keep the wheels in place, which are surrounded by washers and two nuts to stop them from coming loose. The axle runs through a brass tee which connects it to a vertical pipe which then connects to the handle. The vertical pipe runs through a brace which is bolted to the front of the frame. Over the vertical pipe is a hollow pipe with a hole towards the bottom. The vertical pipe contains seven holes each an inch apart, all located above the brace. The two pipes are connected with a hitch pin. This allows for the front handle to be adjustable. The hollow pipe can be raised or lowered according to the user’s height. The handle also contains a mechanism that allows for the arms of the handle to be lowered and raised and tightened in place. When the cart is connected to a hitch for transportation, the handle will be lowered as much as possible and the arms will be turned down. When in use, the handle can be raised.

4. Evaluation

4.1 Overview

Using the requirements listed in Appendix B, various testing methods were used to ensure that the Ultimate Beach Cart exceeds its basic functional requirements. The physical requirements for the Ultimate Beach Cart were evaluated through experimental testing and observation by the mechanical engineers of the group. These requirements include the overall weight of the UBC, connectability to a standard hitch, functionality of the electric drive system, maximum weight the UBC can support, and the ability to drive on different terrains. These requirements were tested in the field, outside of the lab. The electrical requirements were tested by the electrical engineer of the group. These include the voltage and capacity of the rechargeable battery as well as the output of the solar panel, which were tested with a multimeter in the lab. A full description of each requirement, equipment needed, and test procedures can be found in Appendix C.

4.2 Testing and Results

In order to test a majority of our requirements we decided it was best to bring the prototype into a setting where it would realistically be used. Our team decided to test at a local beach lake near Binghamton University. This allowed our team members to simulate realistic working conditions in order to evaluate how the cart performed. All of the requirements and their respective testing procedures can be seen in Appendix C.

In order to determine if the beach cart was under 70 lbs (Requirement WCP52-R-01) we placed it on an industrial size scale at the machine shop in the Engineering Building. Unfortunately our prototype was above the weight limited with a measured weight of 95.4 lbs.

In order to determine if the beach cart could attach to a standard hitch (Requirement WCP52-R-02) we first placed the prototype in the retracted position and then had two members lift and attach the cart to our friend's van's hitch. When we were finished, we had two members remove the beach cart from the hitch.

In order to determine if the beach cart is able to support loading of up to 200 lbs (Requirement WCP52-R-03) we measured various objects that totaled up to 200 lbs and proceeded to incrementally add them to the cart, being sure to note how the loading was portrayed in the deformation of the treads and front wheels.

In order to determine if the beach cart had an electric drive system operable by one user (Requirement WCP52-R-04) we had one person turn on and test that the motor worked when the throttle was pressed.

In order to test that the beach cart could be steered and move in the forward and reverse directions (Requirement WCP52-R-05) we put our cart in the upright position and used the throttle to move forward and backwards.

In order to test that the beach cart could traverse over different types of terrain (Requirement WCP52-R-06) we took our cart to a local beach lake that had different terrains such as gravel, grass, sand, and cement. We placed a 200-pound load on the cart and steered the beach cart through all four types of terrain. The cart showed little to no resistance to the cement, gravel and grass which resulted in a speed that was faster than anticipated. To combat this, we did not twist the throttle all the way in order to find a comfortable walking pace on these terrains. When we got to the sand with the 200-pound load, the cart moved at a perfect walking pace and the motor did all of the work in moving the cart. We did not have to exert any energy moving the cart on the sand.

In order to test that the solar panel on the beach is operable and can generate a current between 0.5 - 2.1 amps (Requirement WCP52-R-07) we went to the beach lake where our cart was exposed to plenty of sunlight and tested the current using a multimeter. The reading shows current is around 0.6 amps, which satisfies our requirement.

In order to test that the battery powering the beach cart was rechargable (Requirement WCP52-R-08) we allowed the battery to fully drain and then left it in the charger for an extended period of time. Afterwards we took a voltage reading across the battery and compared this to the voltage that the battery could support. When battery is fully charged, the voltage is around 25.6 V.

4.3 Assessment

Upon completion of the Ultimate Beach Cart prototype and rigorous field testing, our group WCP52 has compiled a list of methods to further improve the functionality and design of the project for future teams. The Ultimate Beach Cart prototype met every requirement except for the weight requirement. The original requirement stated that the cart shall weigh less than 70 pounds, because 70 pounds is an OSHA requirement for how much weight two people can safely handle. The cart ended up weighing over 70 pounds. We have deduced that this is because the treads became much heavier than originally anticipated. The change from a three sprocket to two sprocket tread system led to adding additional parts that greatly increased the weight of the treads. Also when getting parts machined for the cart, a few parts had to be made with more material than originally planned. This was due to inexperience with the machining equipment, limited access to certain equipment, and the machinists extensive amount of work limited the time they had to make our parts with less material. Another improvement we could make to improve functionality is on our front handle and axle assembly. This assembly was made entirely from scrap metal so we spent zero dollars on this section of our beach cart. With some more funding we would have made a more firm, robust handle. We also would have been able to create a handle that is more accessible to the throttle and reverse button. The cart is made to be steered with one hand while walking next to the cart which is why these improvements need to be considered to improve usage. Next the wiring of the cart could have made to be much cleaner. As it stands the wires are partly hidden and partly out on top of the cart. Also the solar panel charging station is not fully mounted to the cart. Besides these few problems the Ultimate Beach Cart prototype ran at full capacity as expected. It is able to traverse the multiple different terrains without a problem and the battery pack is able to run for up to an hour without dying. It is also to able to handle over 200 pounds without failure.

5. Budget and Schedule

Below is a table outlining the budget of this project.

Item	Original Estimate ($)	Actual to Date ($)	Estimate to Completion ($)	Actual at Completion ($)
Frame	70	66	0	66
Wheels	80	80	0	80
Motor	75	75	0	75
Treads	250	297	0	297
Solar Panel	70	107	0	107
Battery	0	0	0	0
Handle	75	0	0	0
Misc.	0	100	0	100
Total	620	725	0	725

Table 1: Budget of the Project

Below is a table outlining the major milestones of the project as well as the dates they shall be completed by.

Description	Percent Complete	Date of Completion
Project Launch	100	09-21-2015
Requirements Analysis	100	10-26-2015
Interim Report	100	12-04-2015
Interim Presentation	100	12-11-2015
Test Plans and Procedures	100	03-04-2016
Completed Prototype	100	03-15-2016
Testing Complete	100	04-01-2016
Final Report	100	05-04-2016
Final Presentation	0	05-11-2016

Table 2: Project Schedule

6. Future Plans

Our Ultimate Beach Cart could absolutely become the future of transporting waterfront gear to the beach. After discussing what is next for our prototype, we realized that our Ultimate Beach Cart is not quite ready to be made available to the open market. We believe that our design is very successful and achieved what we wanted it to do, but there are small features that should be incorporated into our design.

First and foremost, the wiring of the cart needs to be tampered with so nothing is exposed or in danger of disconnecting. The housing we used for this was very cheap material that we could not even fasten to the frame of the Ultimate Beach Cart. This is a very easy fix because there is plenty of room inside the cargo carrier where we are able to screw these housings in. After the wiring is fixed up we have to work on decreasing the weight of the cart. In order to meet OSHA standards we would need the cart to weigh about 25 pounds less. In order to decrease the weight, we would have to get our machined parts made with less material. Specifically, the tread tensioners and the motor mount could be made much lighter without jeopardizing the integrity of the design. Additionally the front axle design can be improved by increasing its stability. It could also be made so the throttle and reverse button are more attainable to the user's comfort.

We must also consider the possibility of producing this product in mass quantities. The cost of the tread system, cargo carrier, wheels, and metal would be greatly decreased if bought in bulk. This would also be a very appealing product for any beach goers with a standard hitch on their vehicle or people who use a boat to get to the beach.

7. References

1) WCP40 Motorized Mobility Assistance Device Project Report (PR) 2014-05-02
2) MCP73871 Datasheet
3) Adafruit USB/DC/Solar Lithium Ion/Polymer Charger - V2

Appendix A: Project Proposal

BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK
Thomas J. Watson
School of Engineering
and Applied Science

Watson Capstone Projects
Project Proposal Form

Computer, Electrical, and Mechanical Engineering
2015-2016 Faculty Version

Please complete the following to submit a project proposal for a multidisciplinary senior capstone project team. Proposals are due by ***August 15th****, with the goal of having sufficient projects for all our ECE and ME seniors before the semester starts.*

Please submit this form via email to watson.capstone@binghamton.edu*, with an appropriate filename and email subject line.*

1. Project Title

Ultimate Beach Cart

2. BU Department Name

Mechanical Engineering

3. Faculty Names, Phone, Email Address

Kirill Zaychik, x73892, kzaychik@binghamton.edu

4. Project Description

A team of students is to design and build a working prototype of an Ultimate Beach Cart (UBC). A motorized (electric drive) device, designed to facilitate delivery and removal of common waterfront gear, such as cooler, beach chairs, canopies etc to and from the waterfronts.

5. Project Requirements

The UBC shall meet the following requirements:

- *Shall be light weight: <= 50 lbs*
- *Shall be capable of supporting 200 lbs worth of equipment*

2015-2016 Version 2015-03-24

- *Shall be equipped with an electric drive system, operable by a single person. The drive system shall be capable of operating without recharge for at least 4 hours under full load.*
- *Shall be steerable*
- *Shall operable on the inclines up to 12%. Special consideration shall be given to ensuring tip/over protection*
- *The device shall be portable: the device can be either foldable, can be disassembled and reassembled by a single person without any special training and/or tools. Shall be transported to and from the site by a motor vehicle equipped with a roof rack, and/or hitch*
- *Shall be equipped with wheels/tracks, which allow traversing a variety of terrain types, such as sand, gravel, grass, etc.*
- *Shall be equipped by a set of energy harvesting devices, such as solar panel and/or wind turbine. The harvested energy shall be used to power an onboard electrical circuit designed to power a series of USB-type power outlets (1 to 2.1 Amps). The latter shall be used to power/charge a regular smart phone, tablet, and/or power a portable USB speaker.*
- *Shall be able to securely stow a standard 60 quart wheeled cooler.*
- *The cart shall be water/sand proof and could be safely operated under a direct sun*

The following are the soft requirements:

- *The UBC should be equipped by a dedicated shade making device to protect any sensitive on-board equipment*

6. Project Graphic

N/A

7. Resources

The estimated project budget is 600$

8. Deliverables and Meetings

November 2015: UBC detailed design, strength analysis, electrical circuitry design and analysis

December 2015: midterm report and presentation

March 2016: UBC working prototype delivery

April 2016: UBC testing phase

May 2016: final report and presentation

9. Recommended Team Composition (3-5 students)

Please indicate the desired number of students from each discipline. Note that occasionally Biomedical Engineering, Computer Science, or Systems Engineering students are also available.

Mechanical Engr: 4 Electrical Engr: 2 Computer Engr: 0

10. Citizenship Requirements (if any)

N/A

11. Team Members (optional)

Appendix B: Requirements

ID Number	Description	Source	Value Range	Qualification Method	Pass/Fail	Comments
WCP52-R-01	Less Than 70 Pounds	Osha Standards	0.5	Analysis		
WCP52-R-02	Suspended by a Hitch	Customer Need	1	Inspection		
WCP52-R-03	Support 200 Pounds	Customer Need	0.25	Analysis		
WCP52-R-04	Electric Drive 1 User	Customer Need	0.5	Test		
WCP52-R-05	Reverse and Steerable	Client Request	0.25	Test		
WCP52-R-06	Different Terrains	Customer Need	0.5	Test		
WCP52-R-07	Solar Panel	Client Request	1	Test		
WCP52-R-08	Rechargeable Battery	Customer Need	1	Test		

Hard Requirements
-Shall be very user-friendly and portable
-Shall be less than 70 lbs
-Shall be supported and suspended by a hitch
-Shall be capable to supporting 200 lbs
-Shall have electric drive system so that it can be operated by a single user
-Shall have the ability to go in reverse and be steerable.
-Shall be able traverse through all types of terrain.
-Shall have a solar panel equipped to power USB outlets for cell phones (0.5 to 2.1 Amps)
-Shall be pulled not pushed
-Shall have a rechargeable battery

Soft Requirements
-Should be water and sand proof
-Should be operable safely under direct sun
-Should provide shade

Appendix C: Test Procedures

Requirement WCP52-R-01

The total weight of the Ultimate Beach Cart shall not exceed 70 lbs.

<u>Equipment</u>

1. Scale

Procedure

1. Put the UBC in the retracted position.
2. Place UBC on scale.
3. Record reading.

Requirement WCP52-R-02

The Ultimate Beach Cart assembly shall be able to connect to a standard hitch.

Equipment

1. Standard Hitch

Procedure

1. Put the UBC in the retracted position.
2. Two team members lift the UBC.
3. The two team members slowly approach the hitch and slide the UBC onto the hitch.
4. Insert and tighten connecting bolt.

Requirement WCP52-R-03

The Ultimate Beach Cart shall be able to support loading up to 200 lbs.

Equipment

1. Load Simulator

Procedure

1. Securely attach UBC to load simulator. It is essential that the equipment is properly connected.
2. Enter the desired loading value into the load simulator interface.
3. Observe the effects of the load simulation on the UBC.
4. Check the load simulator machine for an indicator that the test was successful

---

Requirement WCP52-R-04

The Ultimate Beach Cart shall have an electric drive system that is operable by one (1) user.

Equipment

1. Ultimate Beach Cart

Procedure

1. Put the UBC in the operable position.
2. One member grab the handle and adjust to preferred angle
3. Turn on UBC by pressing power switch.
4. Turn throttle to move forward.
5. Press the reverse switch.
6. Have member move backwards while holding UBC handle.

Requirement WCP52-R-05

The Ultimate Beach Cart shall be steerable and have the ability to move in the forward and reverse directions.

Equipment

1. Ultimate Beach Cart

Procedure

1. Put the UBC in the retracted place.
2. Steer handle to left or right direction
3. Observe if wheels are able to rotate as the same direction of operation
4. Use throttle to move UBC forward
5. Observe if UBC is able to move forward
6. Turn on reverse switch
7. Observe if UBC is able to move backward

Requirement WCP52-R-06

The Ultimate Beach Cart shall be able to traverse along different types of terrain.

Equipment

1. Ultimate Beach Cart

Procedure

1. Members of the team bring the Ultimate Beach Cart to the park.
2. One member drives the cart over the grass.
3. Another member drives the cart over sand.
4. Another member drives the cart over gravel.
5. Another member drives the cart over concrete.

Requirement WCP52-R-07

The Ultimate Beach Cart shall have an operable solar panel that generates a 0.5 - 2.1 amp current to charge USB powered devices.

Equipment

1. Multimeter

Procedure

1. Put UBC in the place where has multimeter
2. Connect multimeter's probes to the output of solar charging system.
3. Record reading that multimeter displays.
4. Check if record matches the range from 0.5 to 2.1 amp

Requirement WCP52-R-08

The Ultimate Beach Cart shall be powered by a rechargeable battery.

Equipment

1. Multimeter

2. Charger

<u>Procedure</u>

1. Put UBC in the place where has multimeter
2. Take battery out from UBC
3. Test voltage of battery before charging
4. Record the voltage reading
5. Use charger to charge battery for one hour
6. Test voltage of battery after charging
7. Record the voltage reading
8. Check if reading changes compared to reading before charg

Appendix D: Design Justification Charts

Wheels vs. Treads

		Wheels		Treads		Hybrid	
Criterion	**Weight**	**NV1**	**W*NV1**	**NV2**	**W*NV2**	**NV3**	**W*NV3**
Cost	0.05	3	0.15	2	0.1	4	0.2
Weight	0.05	3	0.15	2	0.1	3	0.15
Sand	0.2	1	0.2	4	0.8	2	0.4
Grass	0.2	3	0.6	3	0.6	3	0.6
Concrete	0.2	4	0.8	1	0.2	3	0.6
Durability	0.3	3	0.9	1	0.3	4	1.2

SUM	1		1.9		1.8		**1.95**

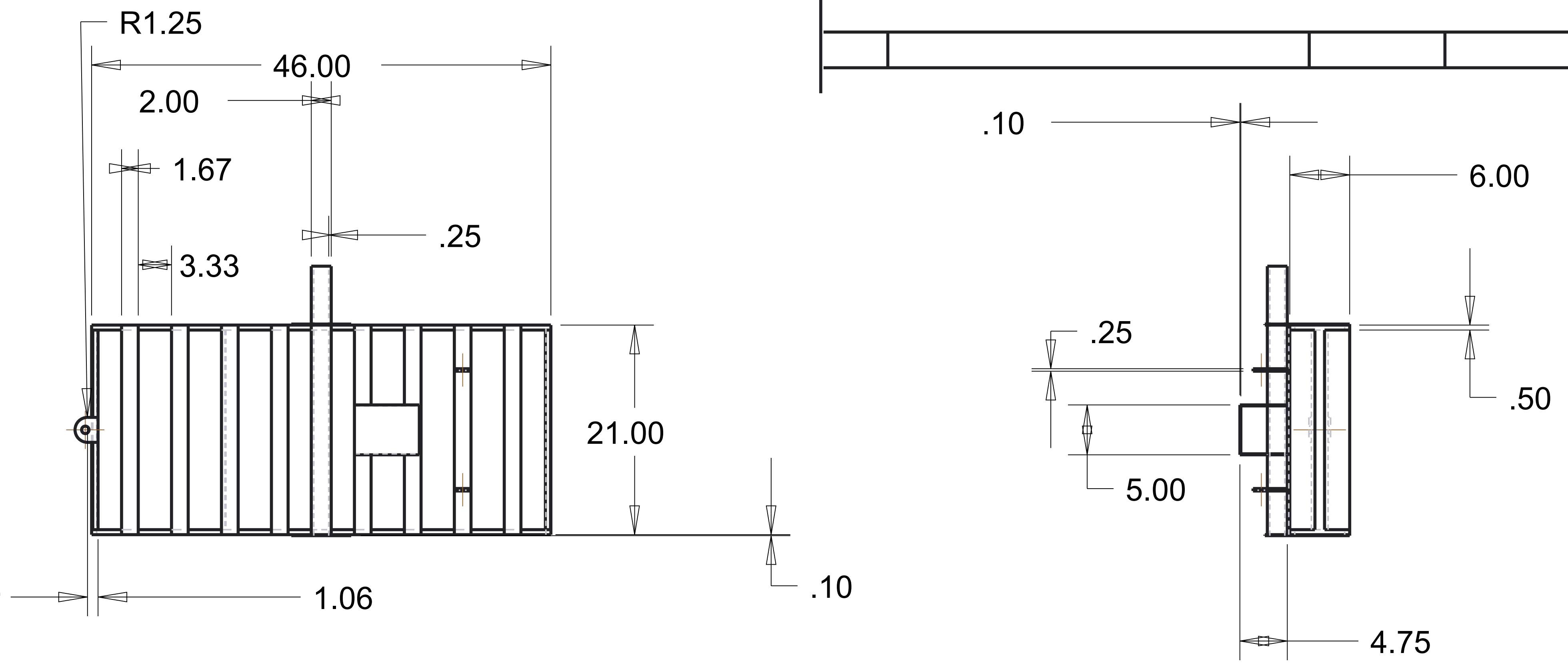
2 Gear vs. 3 Gear Treads

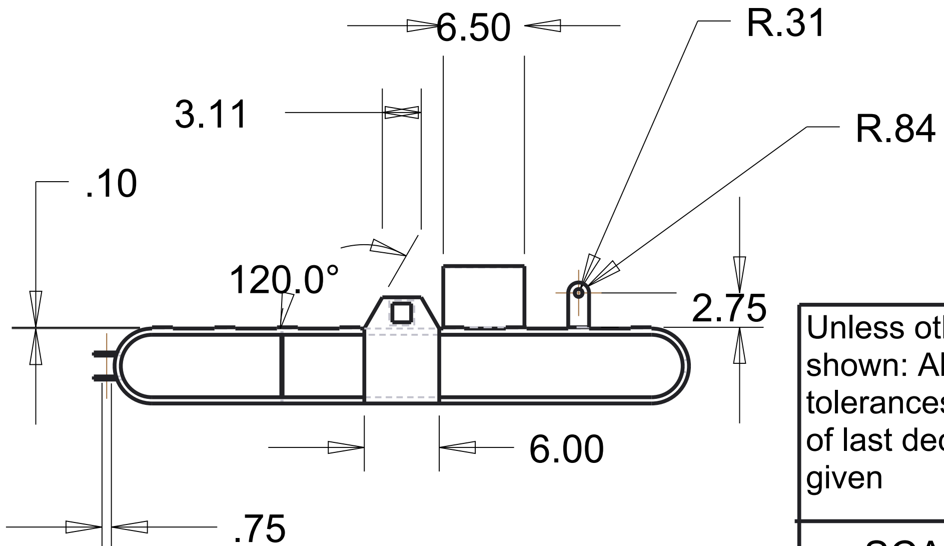
Criterion	Weight	2 Gears	W*NV1	3 Gears	W*NV2
Cost	0.2	3	0.6	2	0.4
Weight	0.1	3	0.3	2	0.2
Durability	0.5	1	0.5	3	1.5
Ability	0.3	1	0.3	3	0.9
SUM	1		1.7		**2**

6V, 2W Solar Panel vs. 6V, 6W Solar Panel

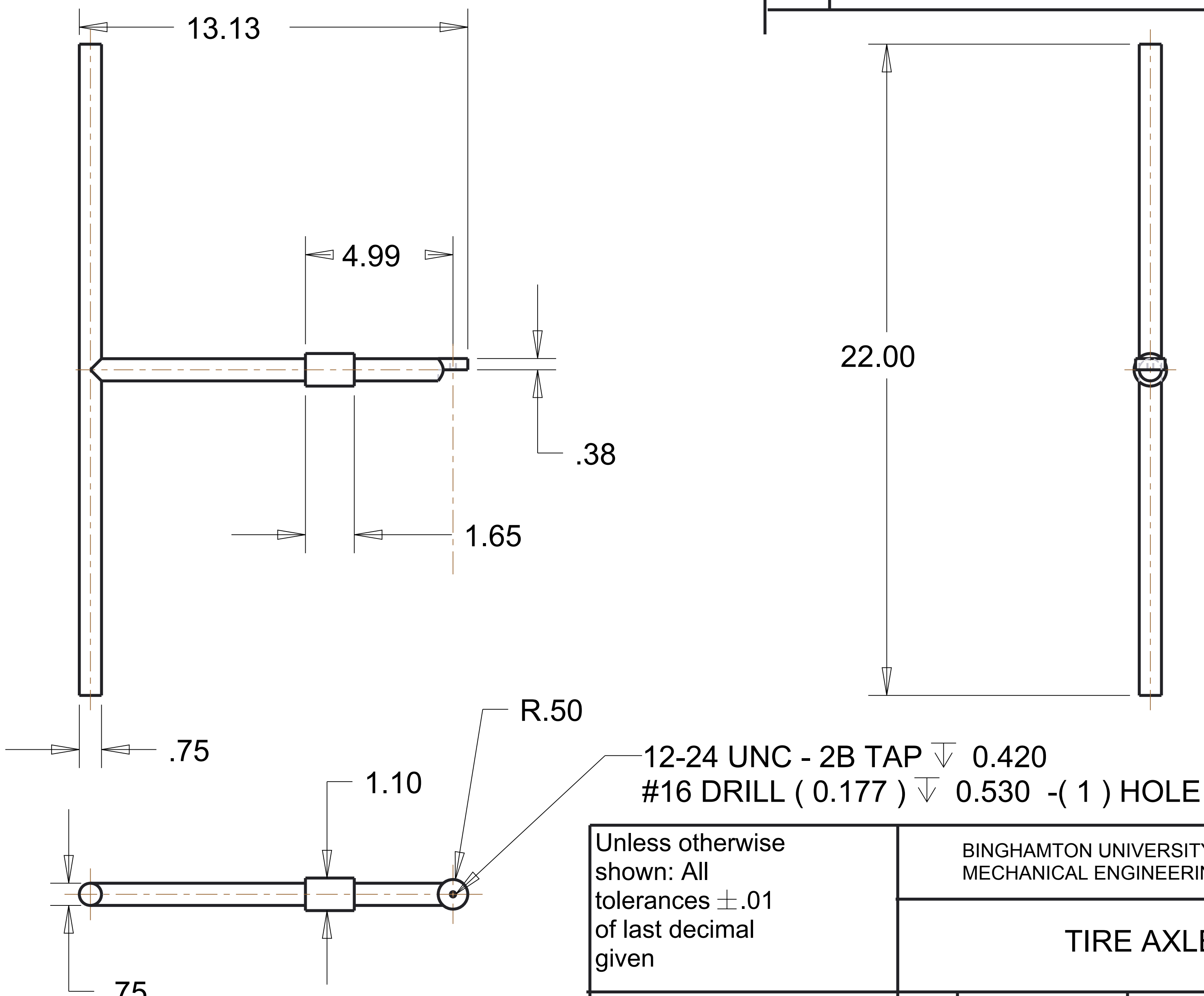
Criterion	Weight	6V, 2W Panel	W*NV1	6V, 6W Panel	W*NV2
Cost	0.4	3	1.2	1	0.4
Efficiency	0.3	2	0.6	3	0.9
Attachability	0.1	3	0.3	3	0.3
Output Current	0.2	2	0.4	3	0.6
Sum	1		**2.5**		2.2

Appendix E: CAD Drawings & Analysis

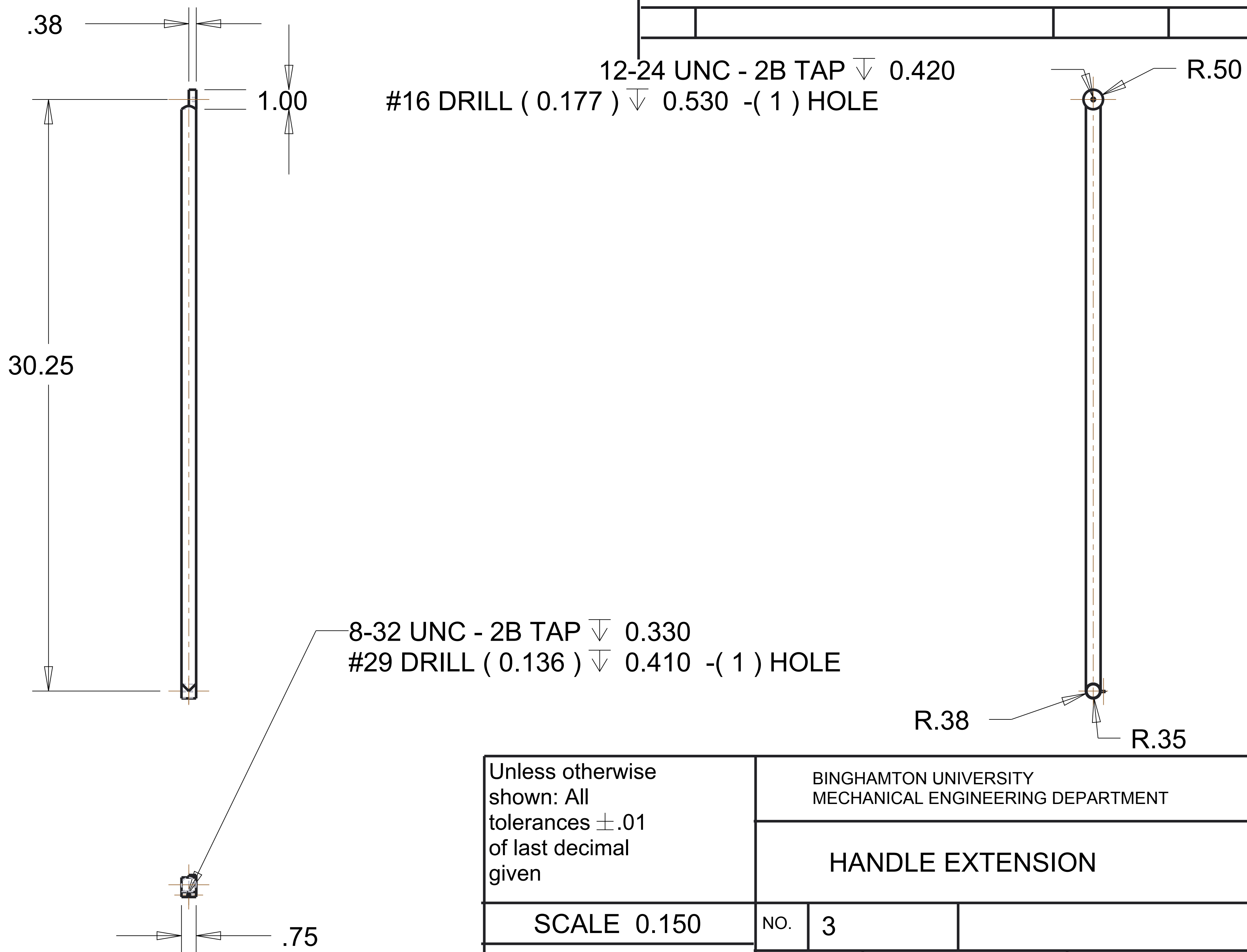




Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT CARGO CARRIER
SCALE 0.065	NO. 1
All dimensions in inches	DRWN BY Tyler Wei DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
	TIRE AXLE
SCALE 0.200	NO. 2
All dimensions in inches	DRWN BY Tyler Wei — DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given

BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

HANDLE EXTENSION

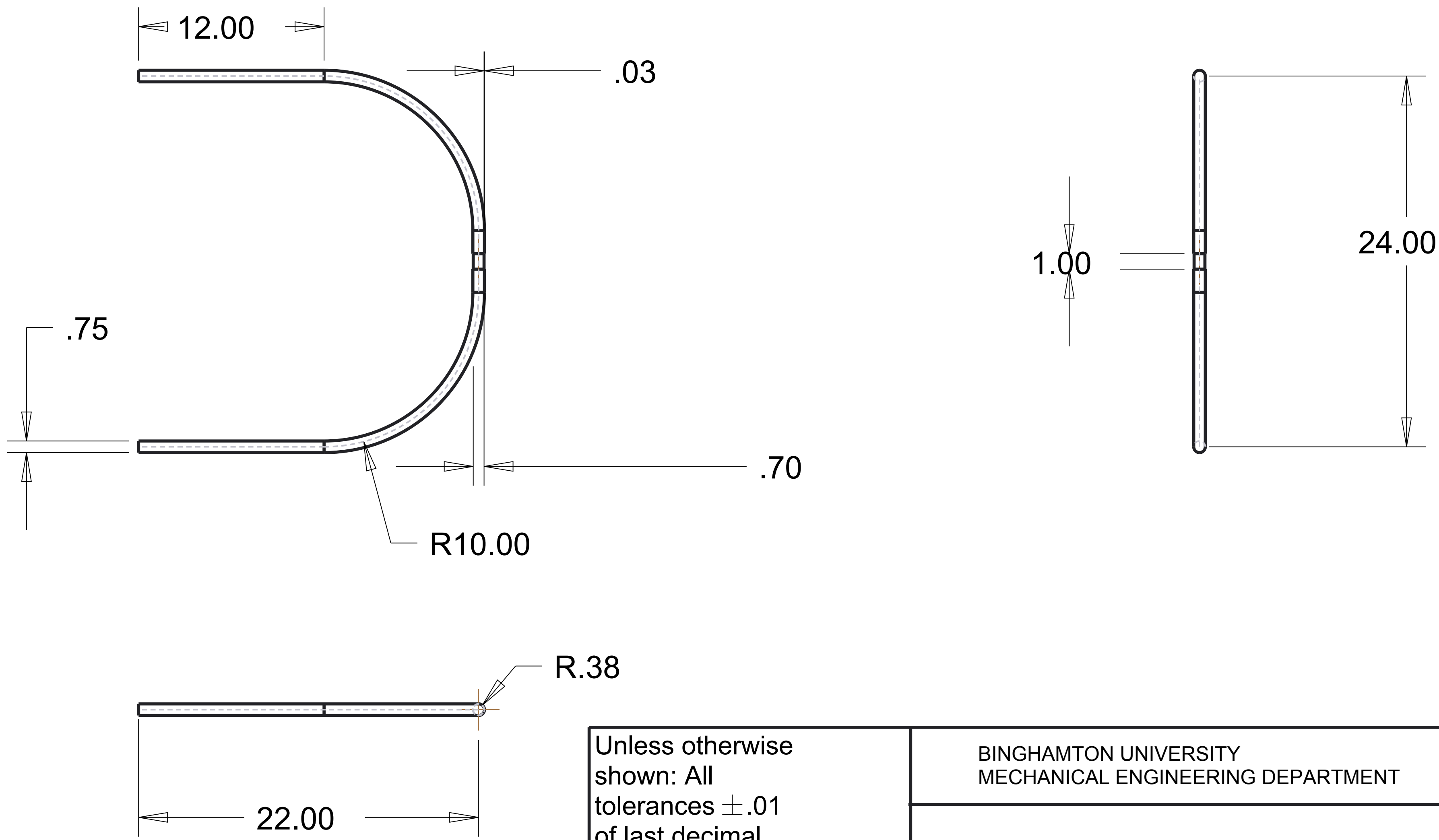
SCALE 0.150

All dimensions in inches

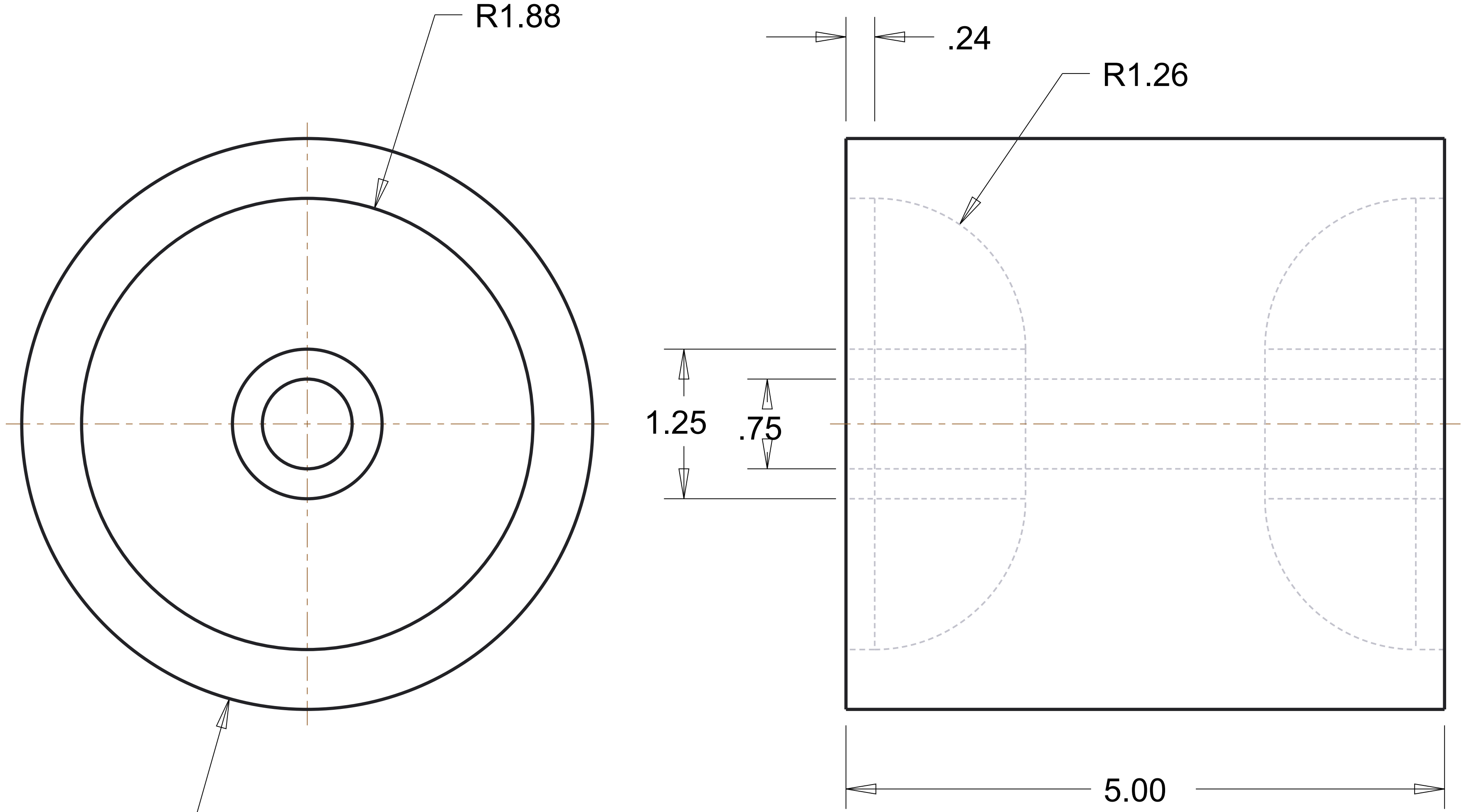
NO. 3

DRWN BY Tyler Wei

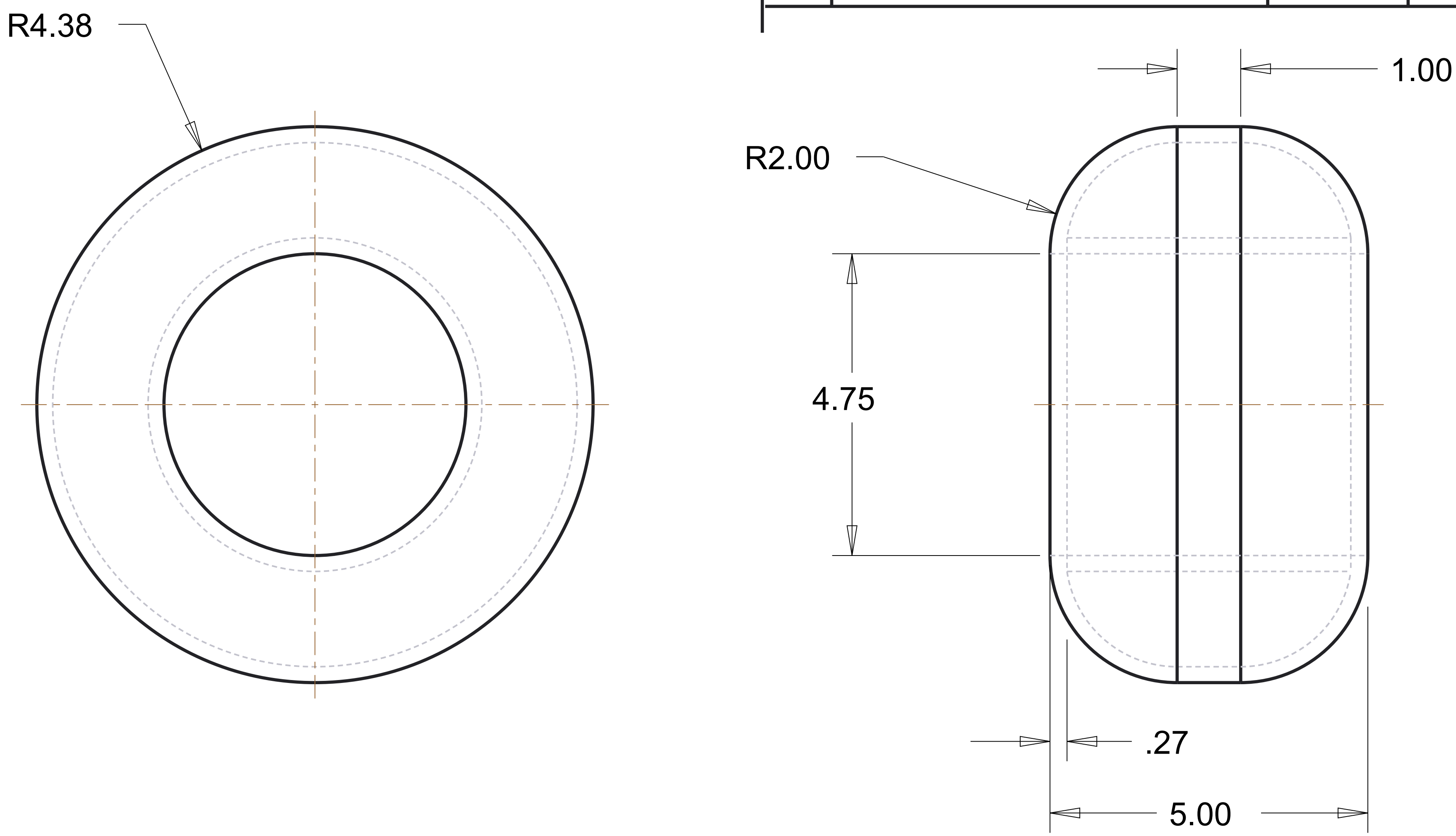
DATE: 12/2/2015



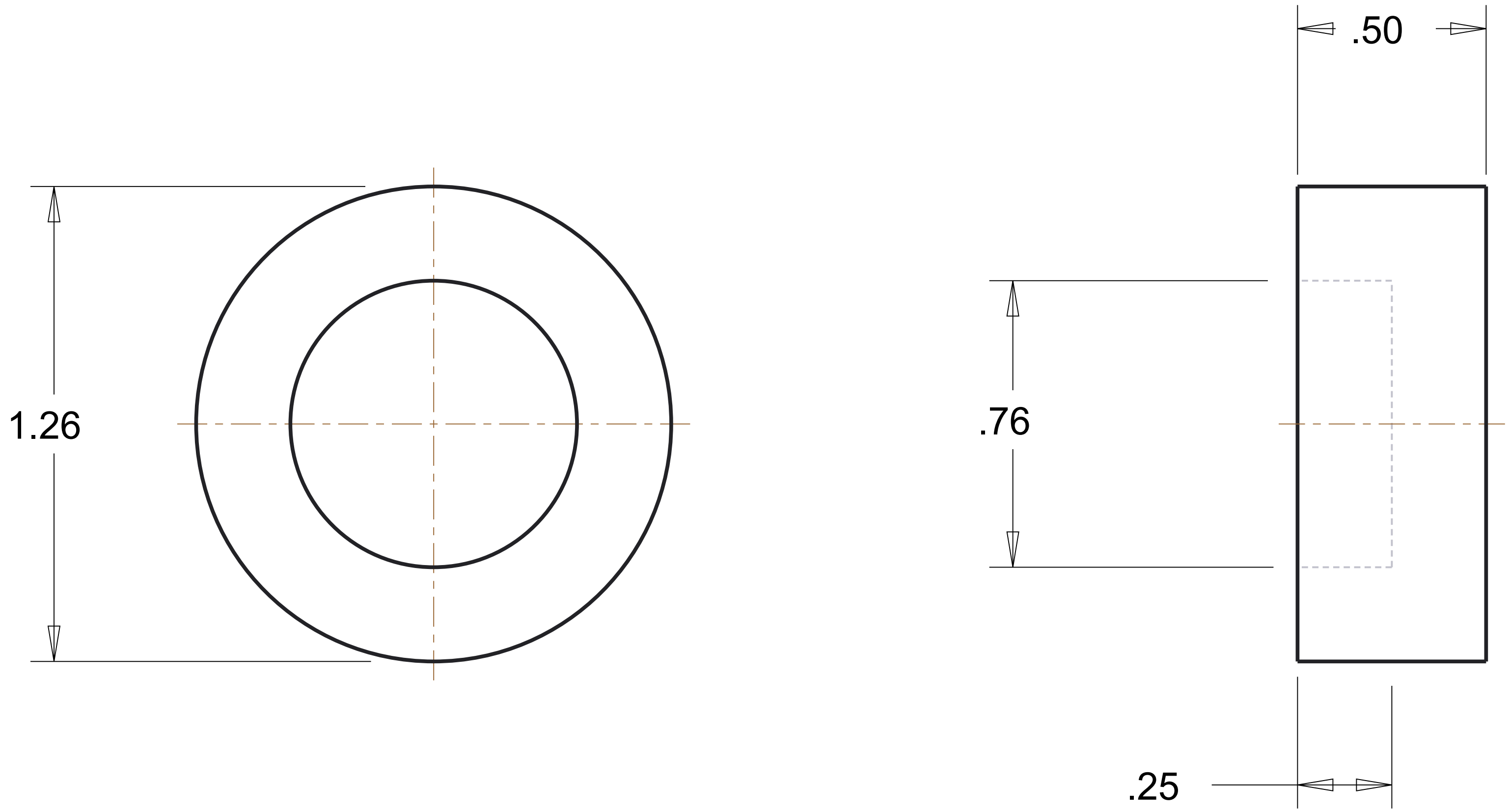
Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
	HANDLE
SCALE 0.100	NO. 4
All dimensions in inches	DRWN BY Tyler Wei · DATE: 12/2/2015



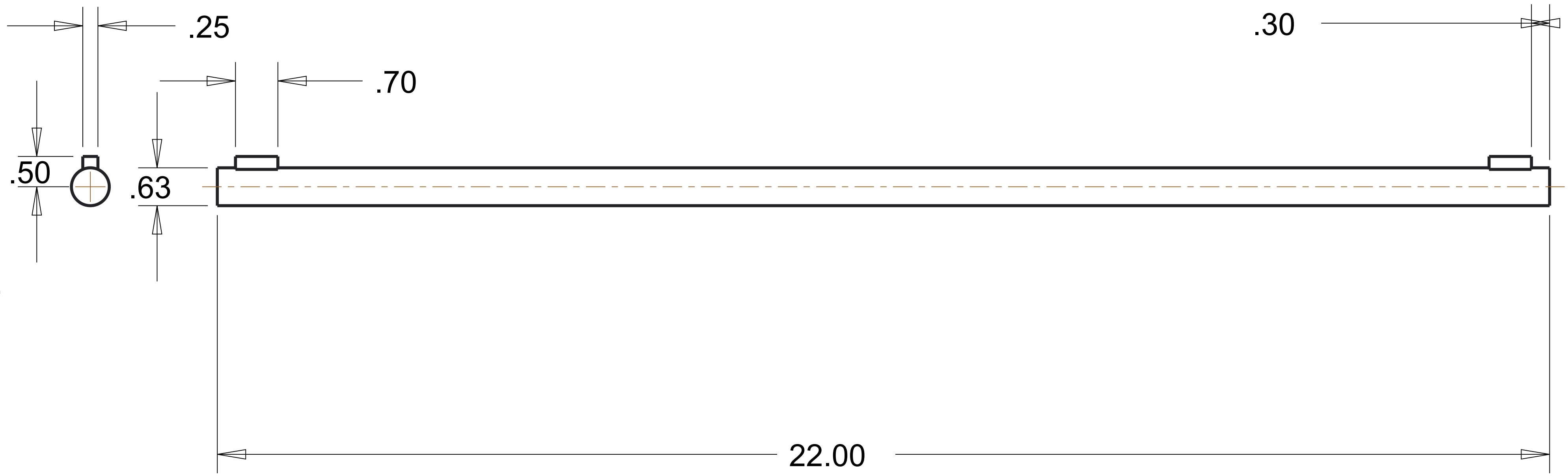
Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT		
	HUB		
SCALE 0.750	NO.	5	
All dimensions in inches	DRWN BY	Tyler Wei	DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
	TIRE
SCALE 0.400	NO. 6
All dimensions in inches	DRWN BY Tyler Wei — DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT		
	WHEEL AXLE CAP		
SCALE 2.000	NO.	7	
All dimensions in inches	DRWN BY	Tyler Wei	DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given

SCALE 0.400

All dimensions in inches

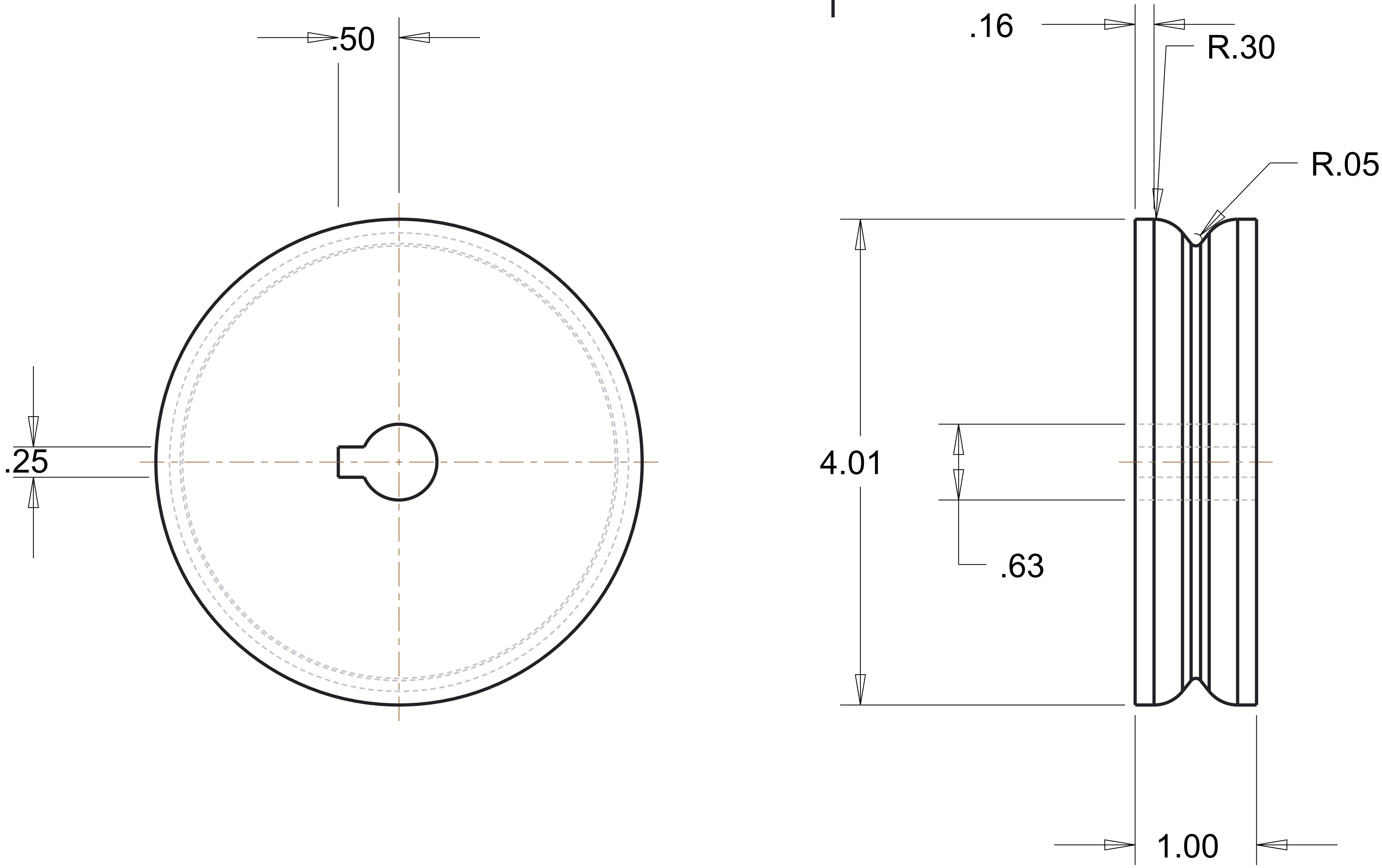
BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

TREAD AXLE

NO. 8

DRWN BY Tyler Wei

DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given

BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

PULLEY

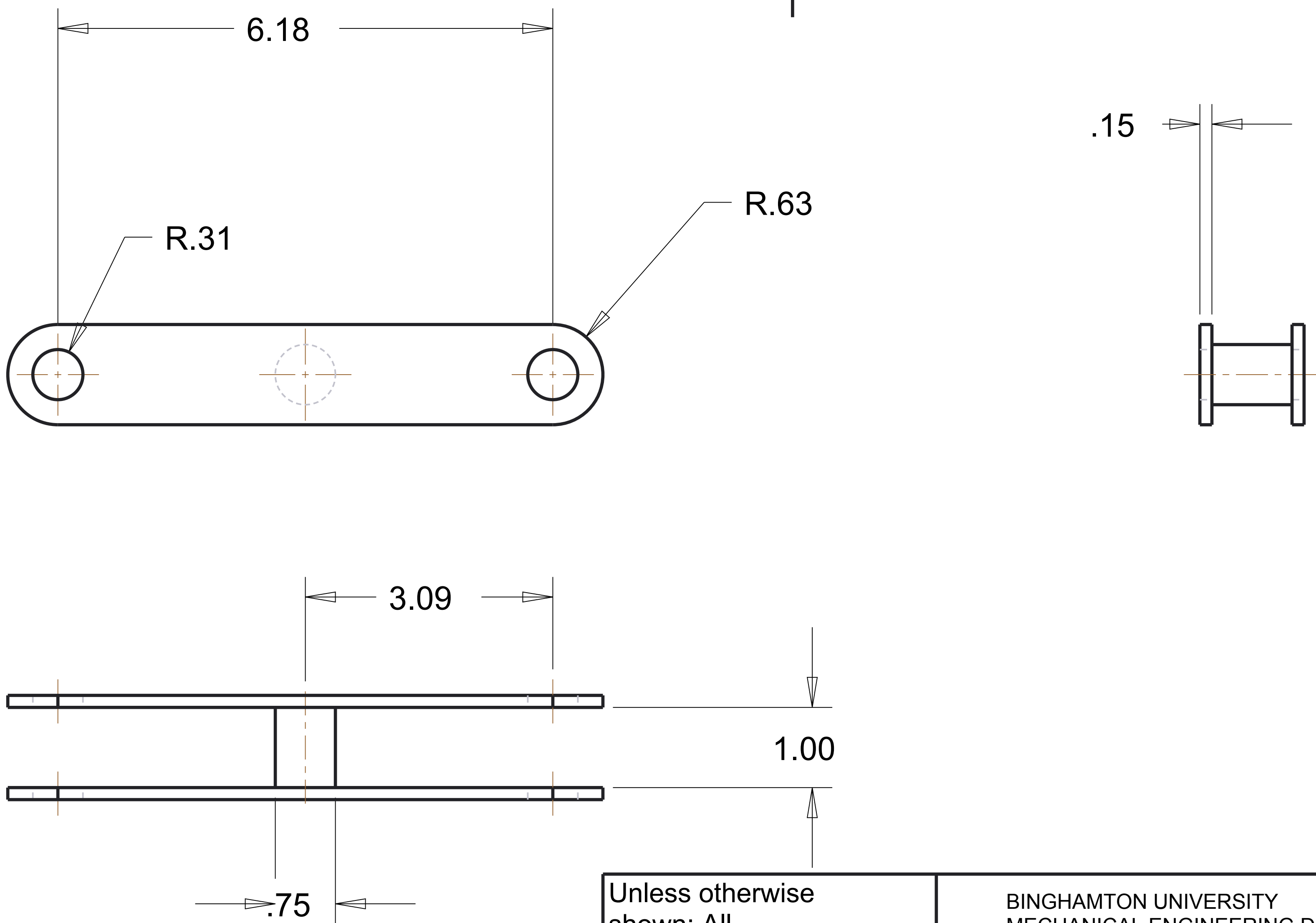
SCALE 0.750

All dimensions in inches

NO. 9

DRWN BY Tyler Wei

DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given

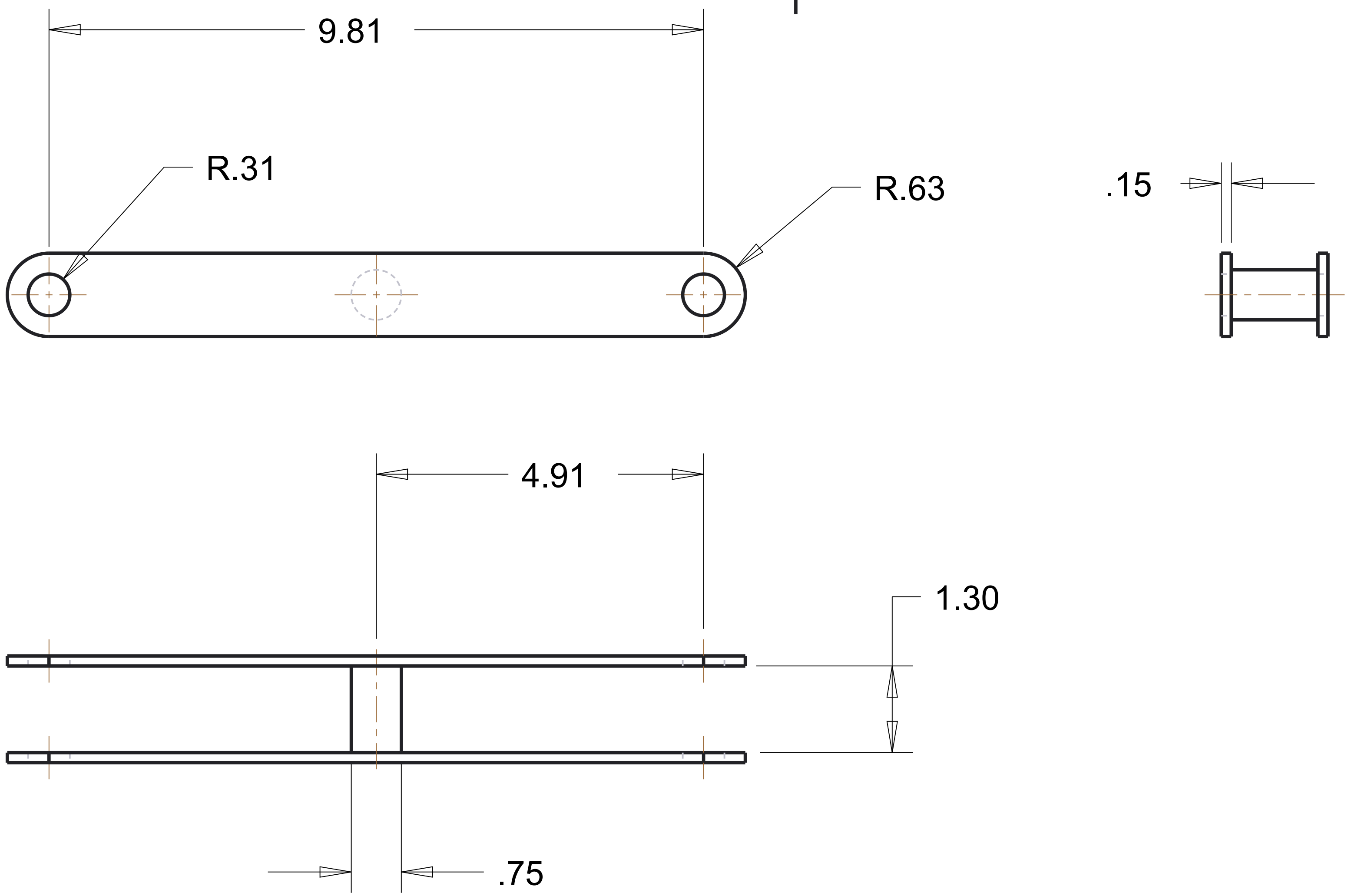
SCALE 0.500

All dimensions in inches

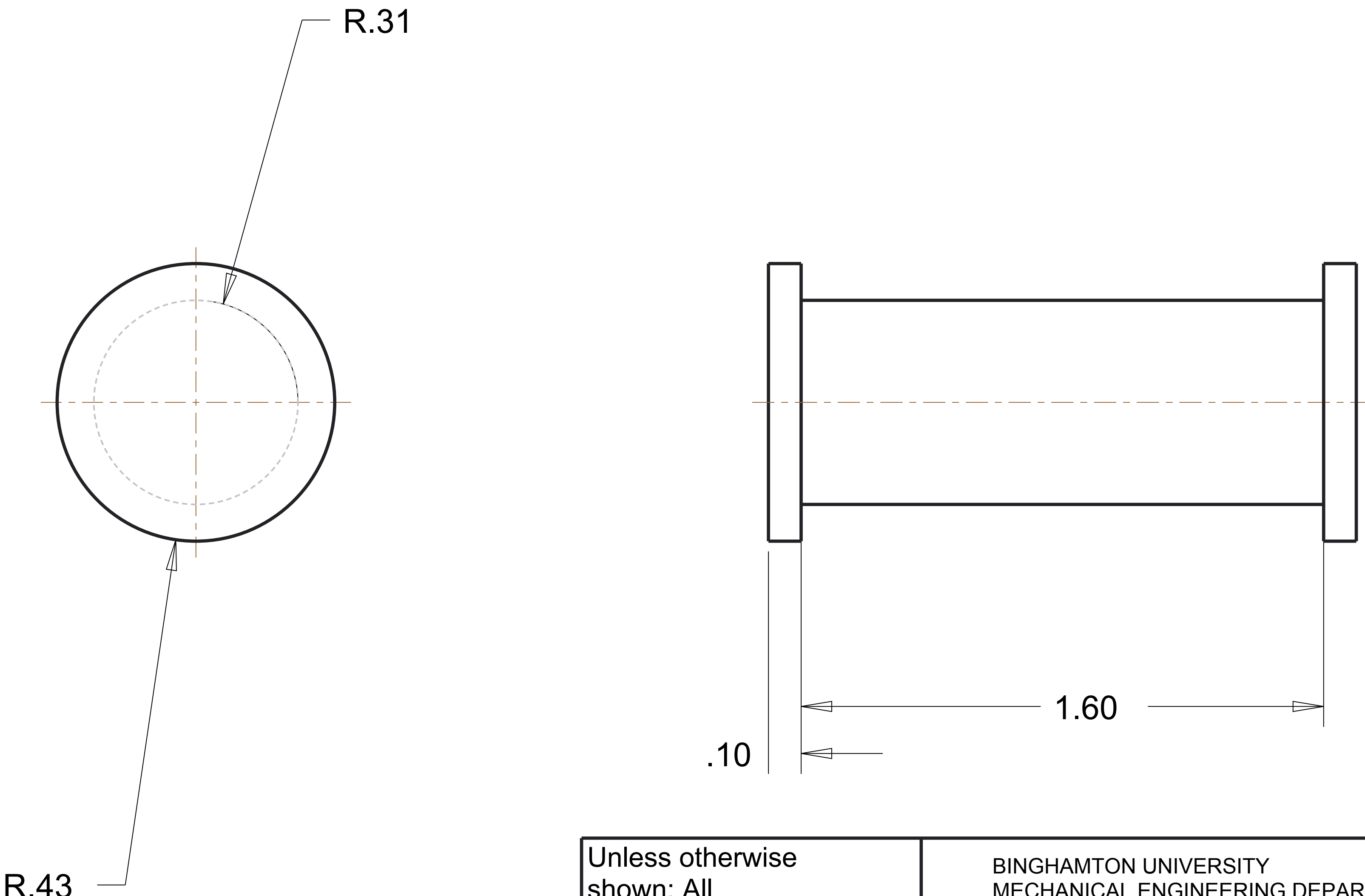
BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

LINK 1

NO.	10		
DRWN BY	Tyler Wei	DATE: 12/2/2015	



Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT			
	LINK 2			
SCALE 0.400	NO.	11		
All dimensions in inches	DRWN BY	Tyler Wei	DATE: 12/2/2015	



Unless otherwise shown: All tolerances ±.01 of last decimal given

BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

PULLEY PIN

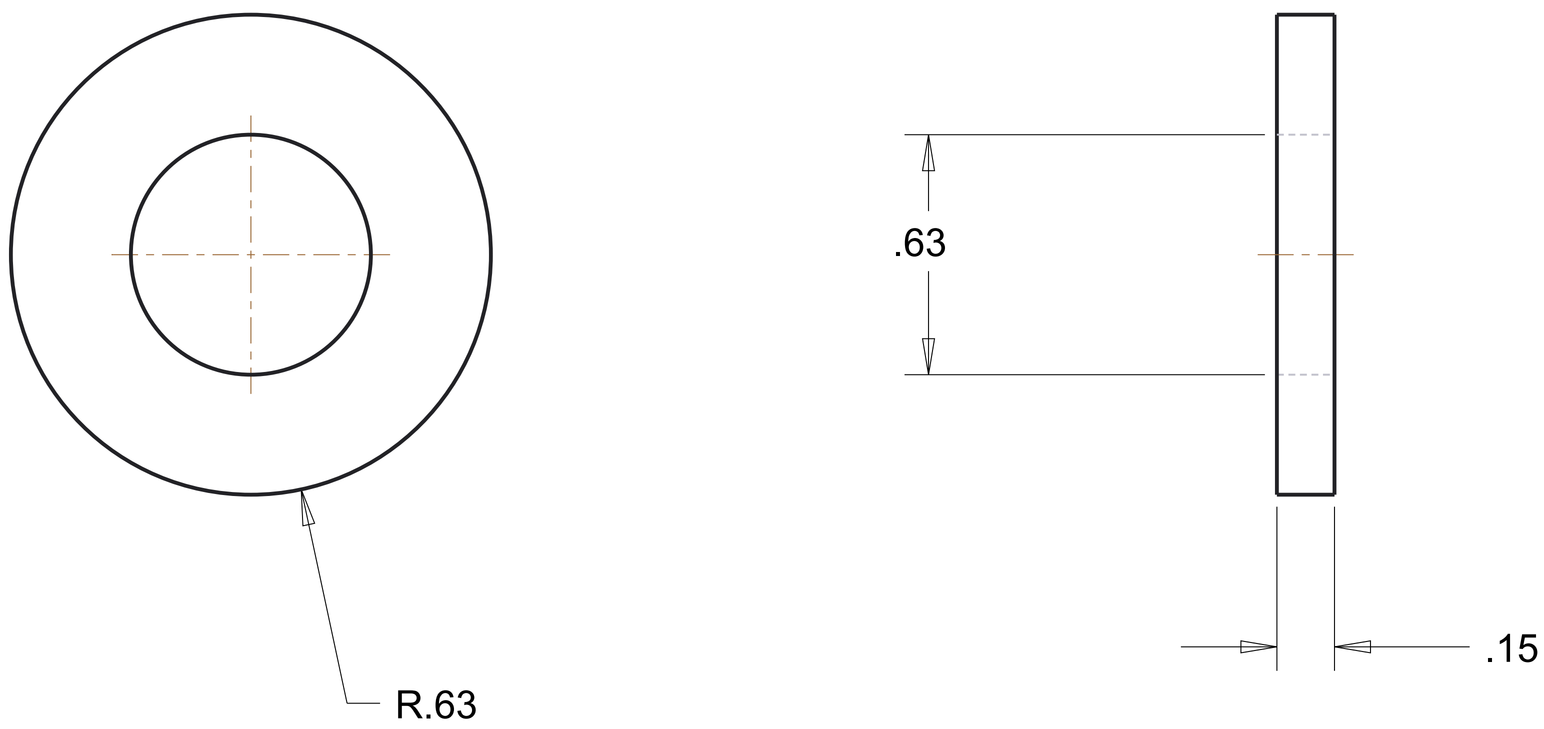
SCALE 2.000

NO. 12

All dimensions in inches

DRWN BY Tyler Wei

DATE: 12/2/2015



Unless otherwise shown: All tolerances ±.01 of last decimal given

BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

WASHER

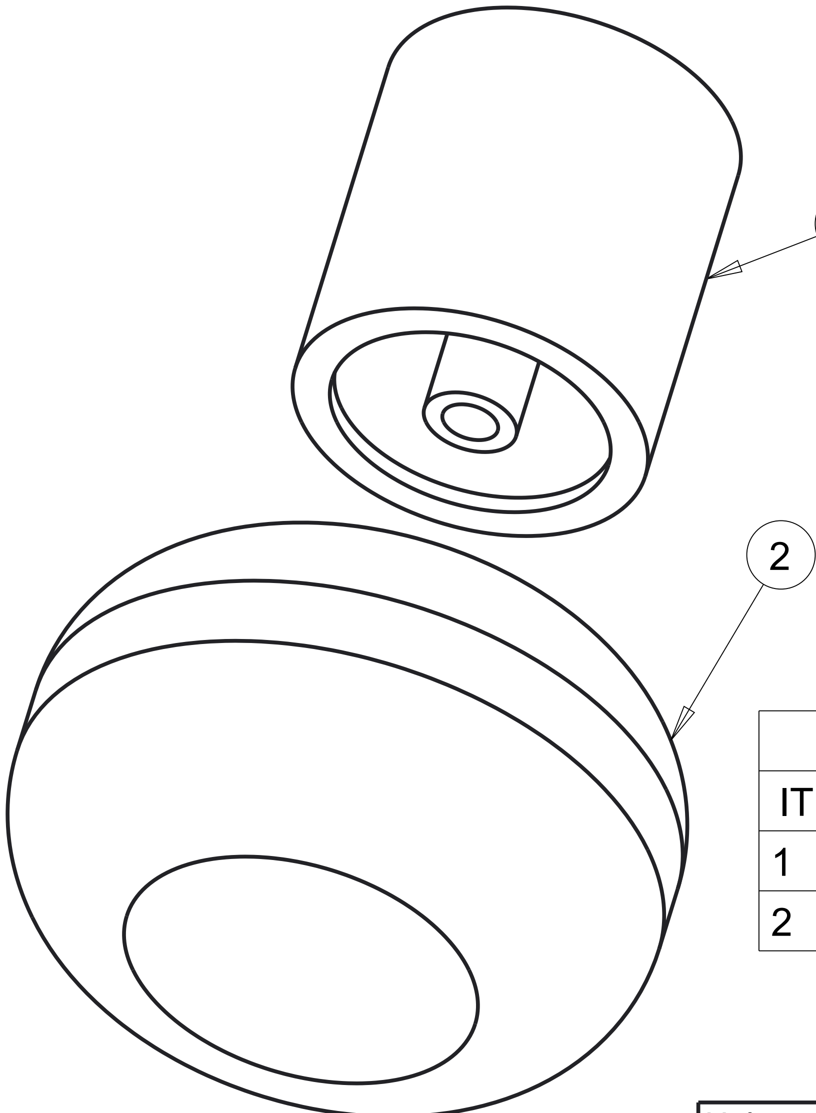
SCALE 2.000

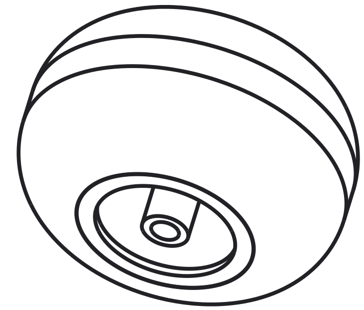
All dimensions in inches

NO. 13

DRWN BY Tyler Wei

DATE: 12/2/2015





SCALE 0.200

BILL OF MATERIAL			
ITEM	DESCRIPTION	QTY	MATERIAL
1	HUB	1	AL6061
2	TIRE	2	POLYSTYRENE BUTADIENE

Unless otherwise shown: All tolerances $\pm$.01 of last decimal given

BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

WHEEL ASSEMBLY

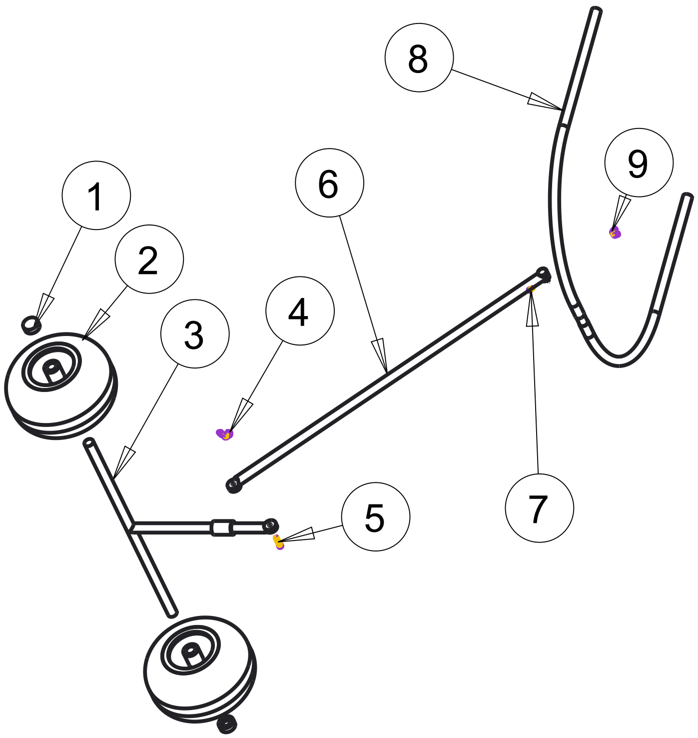
SCALE 0.400

NO. ASM1

All dimensions in inches

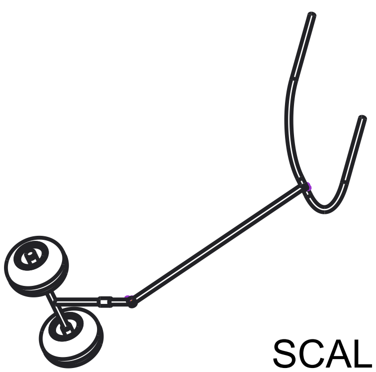
DRWN BY Tyler Wei

DATE: 12/2/2015



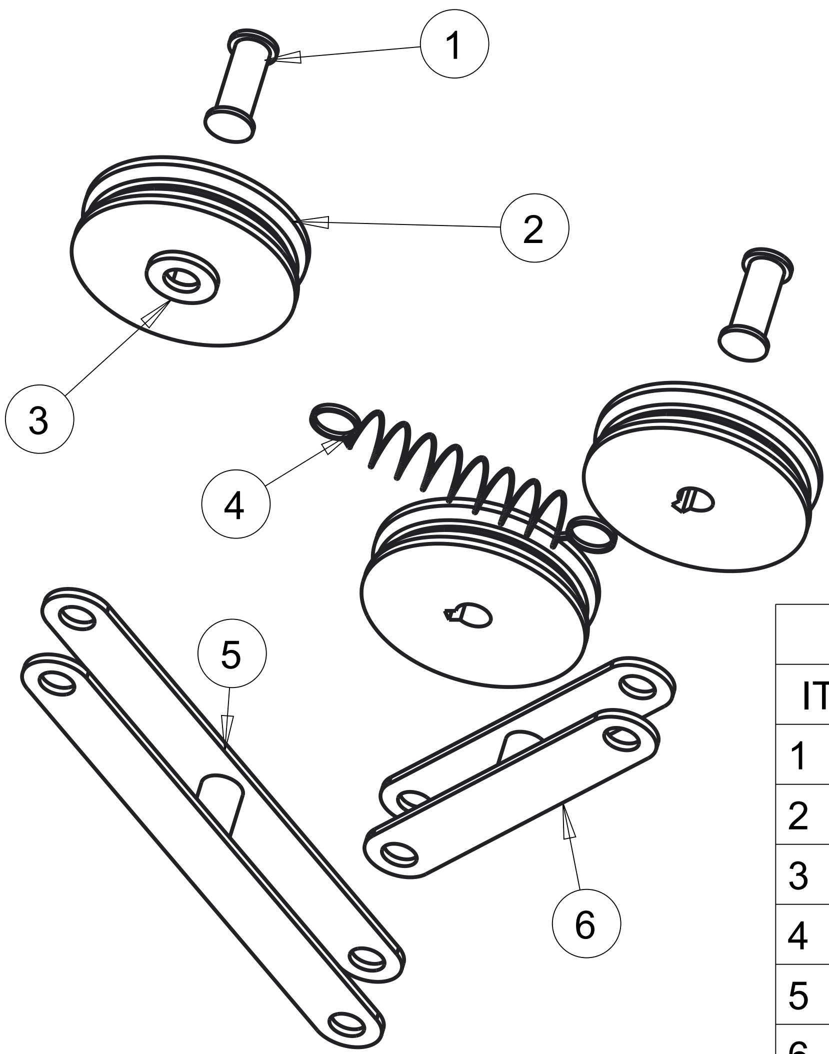
BILL OF MATERIALS

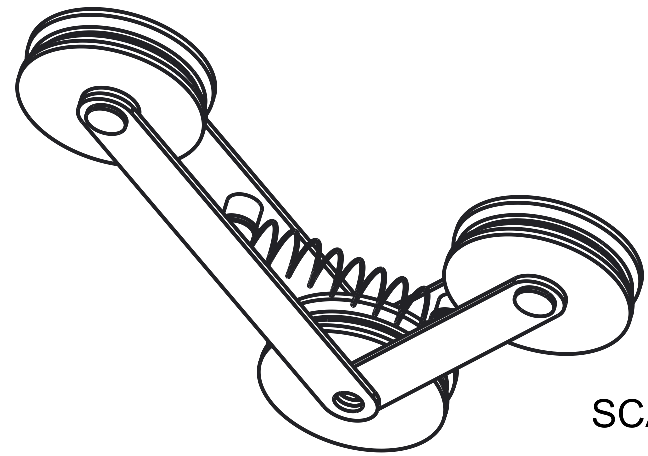
ITEM	DESPCRIPTION	QTY	MATERIAL
1	WHEEL AXLE CAP	2	AL6061
2	WHEEL ASSEMBLY	2	VARIOUS
3	TIRE AXLE	1	AL6061
4	12-24 UNC 2B WING NUT	1	316 STAINLESS STEEL
5	1" 12-24 UNC 2B SOCKET HEAD SCREW	1	316 STAINLESS STEEL
6	HANDLE EXTENSION	1	AL6061
7	1/4" 8-32 UNC 2B SOCKET HEAD SCREW	1	316 STAINLESS STEEL
8	HANDLE	1	AL60261
9	8-32 UNC 2B WING NUT	1	316 STAINLESS STEEL



SCALE 0.036

Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
	HANDLE AXLE ASSEMBLY
SCALE 0.065	NO. ASM2
All dimensions in inches	DRWN BY Tyler Wei — DATE: 12/2/2015





SCALE 0.250

BILL OF MATERIALS			
ITEM	DESCRIPTION	QTY	MATERIAL
1	PULLEY PIN	2	316 STAINLESS STEEL
2	PULLEY	3	AL6061
3	WASHER	1	316 STAINLESS STEEL
4	SPRING	1	316 STAINLESS STEEL
5	LINK 2	1	AL6061
6	LINK 1	1	AL6061

Unless otherwise shown: All tolerances ±.01 of last decimal given

BINGHAMTON UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

TREAD ASSEMBLY

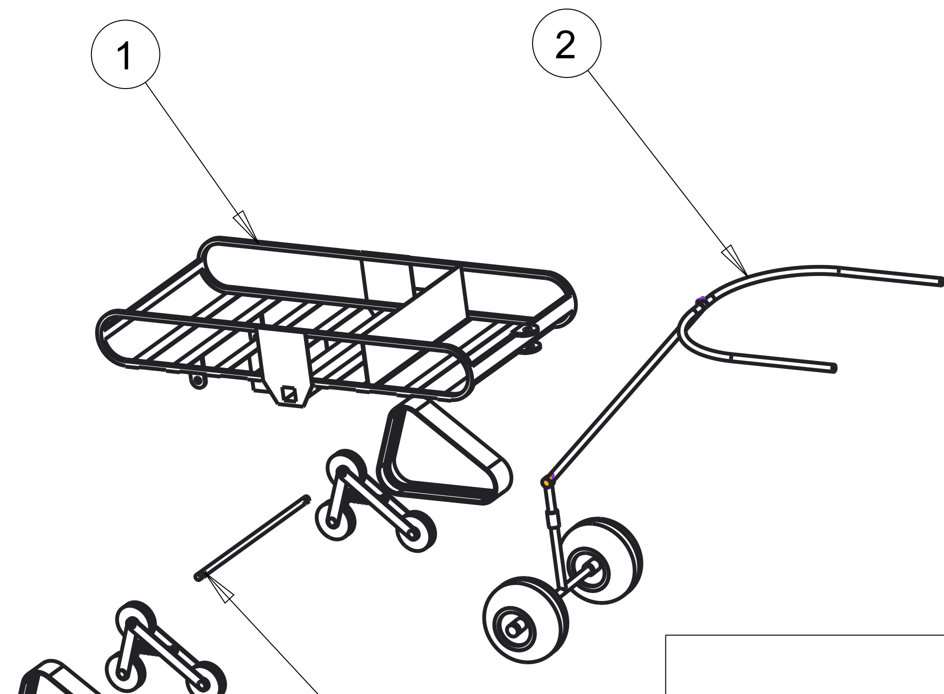
SCALE 0.300

NO. ASM3

All dimensions in inches

DRWN BY Tyler Wei

DATE: 12/2/2015



SCALE 0.050

BILL OF MATERIALS			
ITEM	DESCRIPTION	QTY	MATERIAL
1	CARGO CARRIER	1	AL6061
2	HANDLE AXLE ASSEMBLY	1	VARIOUS
3	TREAD ASSEMBLY	2	VARIOUS
4	TREAD TRACKS	2	POLYSTYRENE BUTADIENE
5	TREAD AXLE	1	AL6061

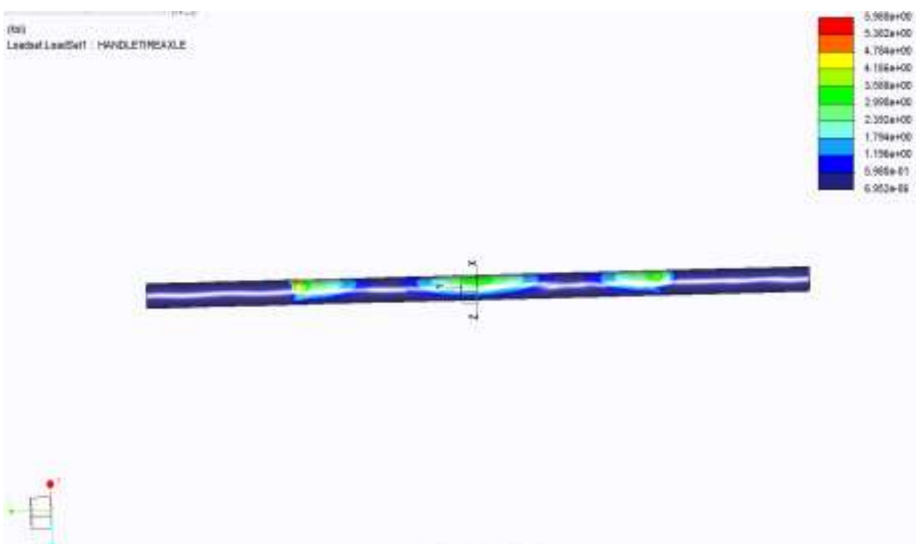
Unless otherwise shown: All tolerances ±.01 of last decimal given	BINGHAMTON UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
	ULTIMATE BEACH CART
SCALE 0.050	NO. ASM4
All dimensions in inches	DRWN BY Tyler Wei DATE: 12/2/2015

Analysis

Analysis 1: Sectioned Wheel Axle analysis

Yield Strength - 35 ksi Max Stress - 0.3609 ksi Factor of Safety - 97

The analysis of the wheel axle occurred in two parts. Diagram 1 shows a load of 100 lbf applied to the thick part of the shaft in order to test if it can withstand the weight of the cargo carrier. Diagram 2 shows a load of 100 lbf applied to the location of the wheels and the center of the



axis where the handle meets the axis.

Analysis 2: Wheel Axle Analysis

Yield Strength - 35ksi Max Stress - 5.98ksi Factor of Safety - 5.85

Analysis 3 shows a load of 100 lbf applied to the locations where the cargo carrier frame connects to the tread axle. For this analysis the axle was constrained on the ends. Analysis 4 shows a 100 lbf applied to the screw that holds the handle to the axle.

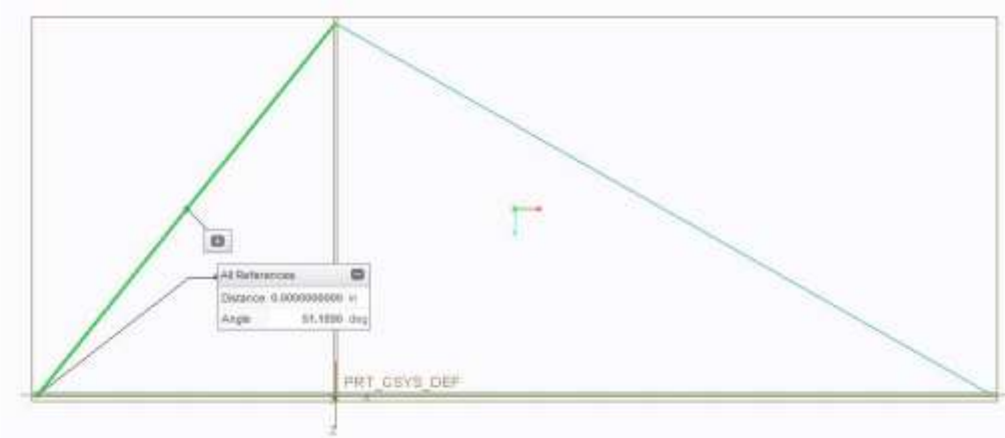
Analysis 3: Tread Axle analysis

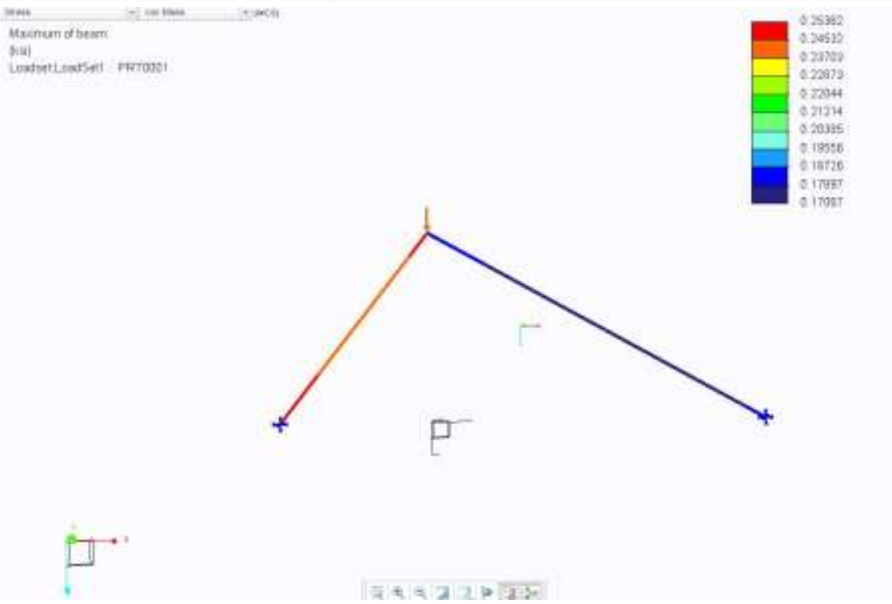
Yield Strength- 35ksi Max Stress- 1.083ksi Factor of Safety- 32.3

Analysis 4: Handle Extension Screw analysis

Yield Strength - 36ksi Max Stress - 9.97ksi Factor of Safety - 3.

Tread Spring Constant (*k*)





To figure out the Tread Spring Constant (*k*), Finite Element Analysis was first run by an idealization of the tread mechanism. For the idealizations, it was determined that by assuming all 200 lbf was applied to the tread axle, each tread which contains two linkage systems would receive a downwards point load of 50 lbf. Upon running FEA it was shown that the maximum von Mises stress (0.254 ksi) would occur in Link 1. The internal forces of this beam was then determined to be 47.6 lbf with the stress force relationship equation as shown below where $\sigma$is tensile stress, F is Force, and A is the cross sectional area which was designed to be 0.15 in by 1.25 in.

$$\sigma = F \times A$$
$$0.25362\ ksi = F \times (0.15\ in\ \times\ 1.25\ in)$$
$$F = 47.6\ lbf$$

After figuring out the internal force, the spring constant k could be determined by taking the horizontal component of the force F and by using Hooke's Law as shown below. In this case, the displacement x was set to be 0.1 inches in that the tread linkage mobility should be limited to a small displacement and θ was set at 51.2 degrees as per the design. The spring constant was determined to be 283 lbf/in

$$Fhoriz = k \times x$$

$$F cos\theta = k \times x$$

$$47.6\ lbf \times cos 51.2 = k \times 0.1\ in$$

$$k = 283\ lbf/in$$