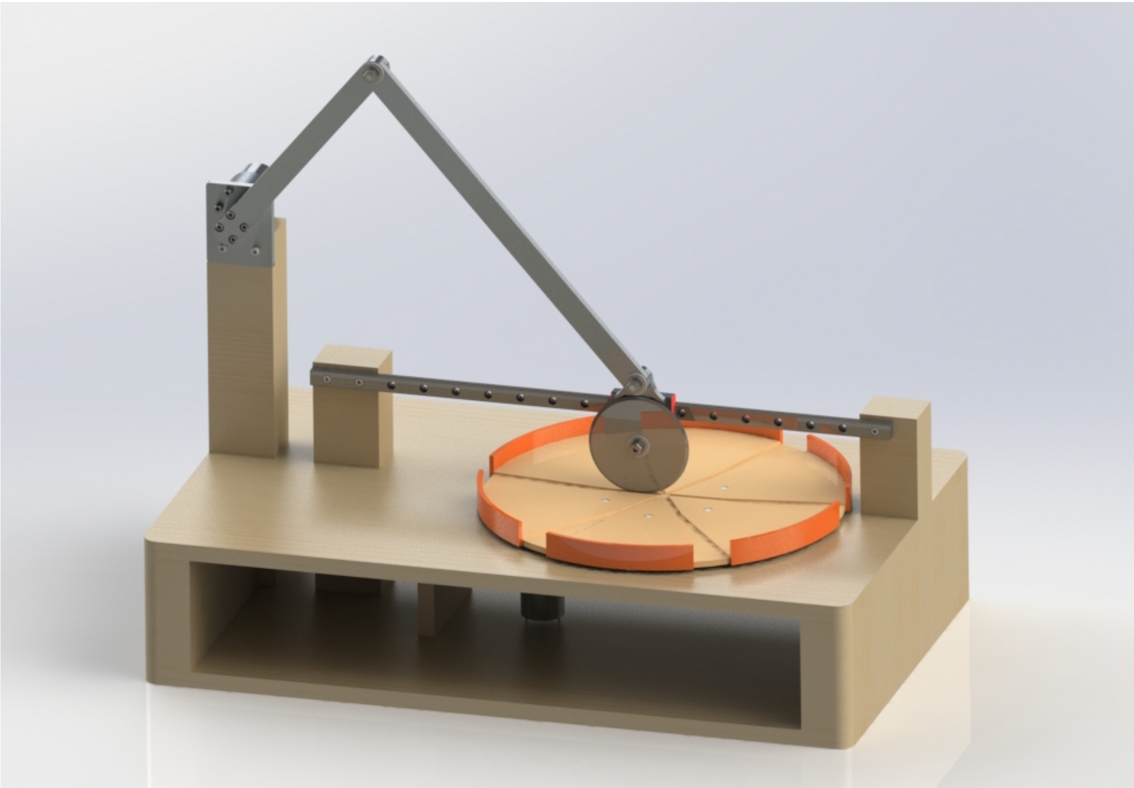
ME 130 Final Project

PizzaBot



Team Members:

Andy Meyers, Andrew Midyett, Palmer Hayward
Ryan O'Bannon, Zach Remland

December 8th, 2016

1 Background

Have you ever made a beautiful, fresh pizza at home? It looks so delicious, but before you can enjoy it you have to go through the hassle of cutting it. If you have ever tried to cut a pizza using a pizza wheel, you know that this can be a difficult and frustrating task. PizzaBot was invented to erase the frustrations of slicing a pizza through automation, thus enabling the consumer to enjoy their pizza to the fullest. Simply flip a switch and PizzaBot cuts a personal sized pizza up to eleven inches in diameter into six slices in only 30 seconds! Gone are the days of struggling to cut a pizza as the hot cheese burns your fingers! In the time that it has taken you to read this paragraph, PizzaBot could have already sliced your pizza for you and you could sit back and enjoy your fresh slice of pie as you read the rest of our report! If that isn't appealing, then I don't know what is!

2 Introduction

The concept behind PizzaBot is that to create a device that automatically cuts a pizza into a certain number of slices. Our device consists of two main mechanisms, an offset crank-slider and a six-pronged geneva wheel. The crank-slider pushes a pizza wheel across the surface of a plate where the pizza sits while the geneva wheel rotates the plate from underneath by 60° after the crank-slider has completed one pass. In this way, the pizza will be fully cut into six slices after three full rotations of the crank-slider and geneva wheel mechanisms.

The crank-slider mechanism consists of multiple parts. It is powered by a 6 RPM motor that is attached to a vertical support 3.6 inches above the steel track that the slider runs along. The crank shaft of the mechanism measures 7 inches in length and is attached to the motor on one end by a set screw motor hub. The other end of the crank shaft has a bearing press fit into it and is attached to the other arm of the crank-slider, which also has a bearing press fit into it, by a steel pin. Nylon washers are place on the outside of the links and in between to allow smooth rotation. A lock nut fixes on the threaded end of the steel pin fixes everything into place. The second arm link, of length 12 inches, is attached to the slider plate in much the same way. A steel pin is inserted into the bearings and nylon washers provide the spacing to allow the connection to rotate. A lock nut holds everything in place. Finally the pizza wheel is connected to the slider by another pin attachment. In place of a bearing, the pizza wheel rotates around a nylon bushing for smooth rotation. A steel pin is passed through the slider plate and the pizza wheel, nylon washers are added, and a lock nut secures the assembly in place. As the motor runs, the crank-slider mechanism rotates and pushes/pulls the pizza cutter across the surface of the cutting platform where the pizza rests, thus cutting the pizza in half.

The geneva wheel mechanism consists of a 6 RPM motor, a drive shaft for the geneva wheel, a lazy susan bearing, a 6-pronged geneva wheel with a diameter of 7 inches, a 3D printed connector between the geneva wheel and pizza plate, and the wooden pizza plate. The motor is secured to a suspended support platform using four small screws. On the head of the motor, the geneva wheel drive shaft is attached using a set screw. The 3 inch lazy susan bearing is screwed directly into the suspended support platform and the geneva wheel is attached to the top half of the lazy susan bearing, allowing the wheel to spin freely. Next the 3D printed connector is attached to the geneva wheel using four sets of nuts and bolts. Finally the pizza plate is pressed into the prongs on top of the 3D printed piece, and the plate rests on a set of four small wheels to allow smoother rotation as the plate moves. As the motor rotates, the pin in the drive shaft slides into one of the slots on the geneva wheel and pushes it forward, thus causing the geneva wheel to rotate 60°. Since all the other parts are attached directly to the geneva wheel, the pizza plate is also rotated by 60°. The timing is such that the geneva wheel begins and completes its rotation in the time that the slider crank is completely cleared of the pizza plate.

3 Specifications

When designing our product, the goal was to create a device that fit on a kitchen counter, could be moved and easily operated by one person, and cut a pizza into even slices relatively quickly. It should also be safe, durable and attractive. Our prototype device fits all these criteria. It's dimensions, 13" x 22" x 15", are comparable to a microwave, the product weighs less than twenty pounds and can cut a maximum 11 inch pizza. Slicing a pizza takes just over thirty seconds. The pizza plate is also removable so preparing and removing the pizza from the device is easy and quick. With a single switch used to turn the mechanism on and off, user interface is simple and easy.

The device runs singularly off of DC power, creating a purely mechanical system. Two motors, each with a speed of 6 RPM, drive the mechanism. One motor drives the slider crank linkage used to cut the pizza and the other drives the geneva wheel mechanism used to rotate the pizza. The motors were selected with a 613 oz-in torque output capacity to provide the minimum required input force of 10 Newtons to cut the pizza. Aluminum linkages and a wood structure were used to ensure durability and provide the desired lifespan of greater than three years. The prototype cost approximately 160 dollars to build, where the most expensive components were the motors and track. A production model would cost less than half of that, approximately 75 dollars.

4 Conceptual Designs

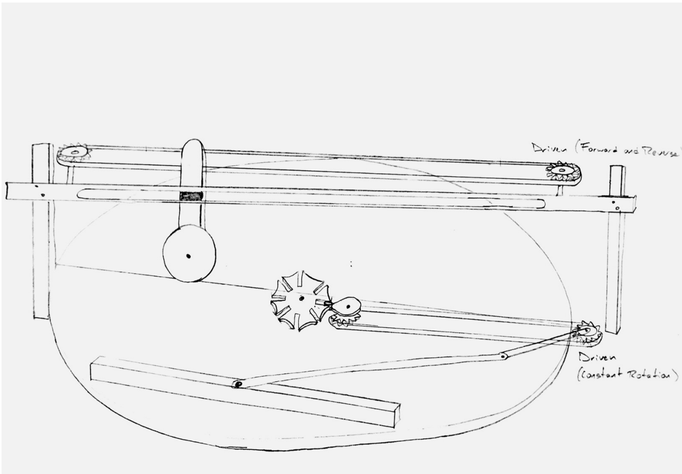


Figure 1: Sketch of initial PizzaBot concept with roller chain mechanism

The initial design for the pizza bot used a roller-chain mechanism to drive the wheel across the pizza. As seen in the sketch above, the blade would be attached to a chain to drive it and also be bolted to a slider that would keep the blade along a straight horizontal line during its motion.

The main concern with the design was applying enough force to cut the pizza and keeping the chain taught during the motion. Additionally, the timing in order to get a motor that provided enough torque would have required excessive gearing that would have complicated the system.

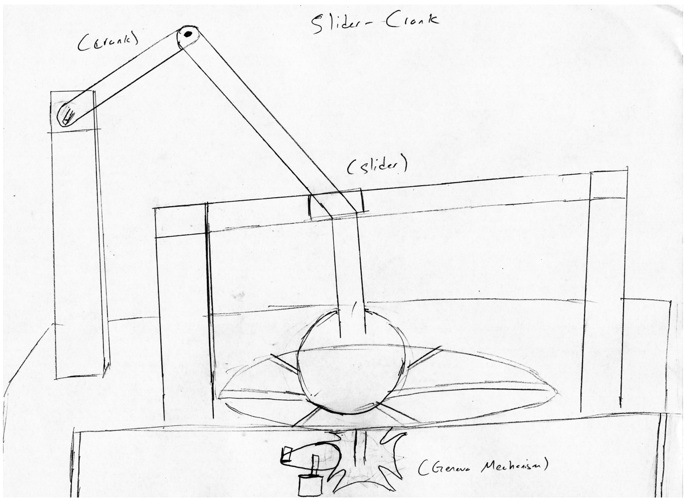


Figure 2: Sketch of final PizzaBot concept with slider-crank mechanism

The final design sketch for PizzaBot is given in the sketch above. A slider-crank mechanism is used.

5 Gantt Chart and Task Distribution

The Gantt Chart outlines the schedule from the beginning of the design phase until the assembly and testing of the project. The CAD design draft stage was the longest portion of this project as the choice between moving the pizza wheel via a chain drive or slider crank mechanism was under consideration and CAD models were made for both.

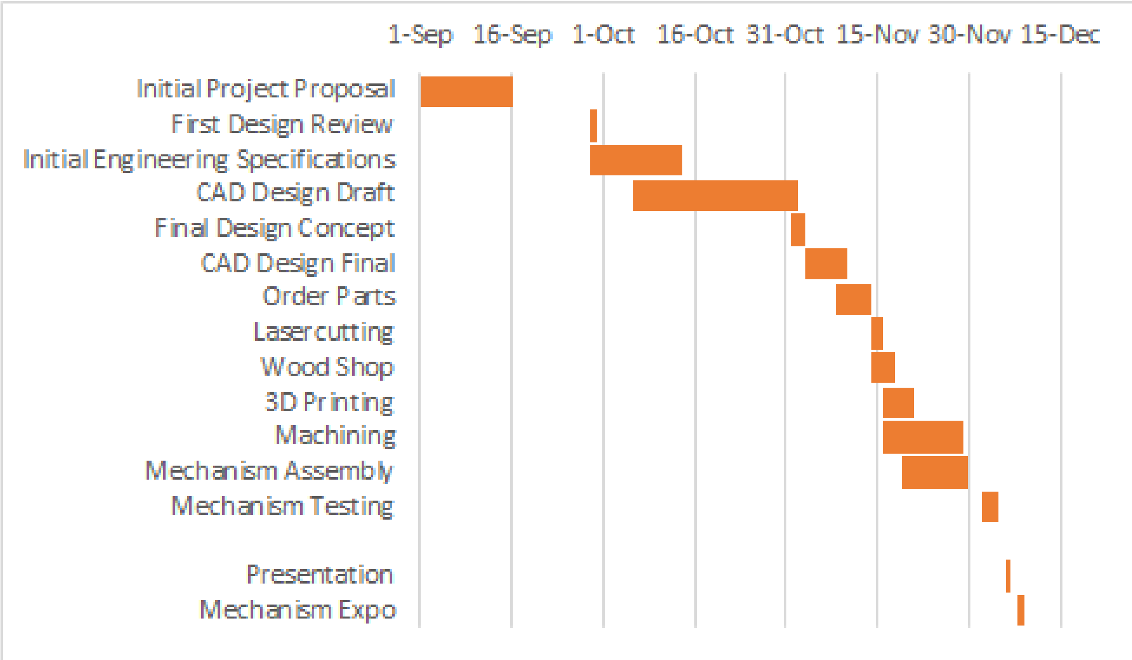


Figure 3: A timeline of the project design and building process

The entire team was involved with the project idea, development, CAD design and project assembly. Three team members, Andrew Midyett, Palmer Hayward and Ryan O'Bannon, were trained in the Etcheverry machine shop and worked on machining the aluminum parts. Andy Meyers and Zach Remland used the makerspace in Jacobs hall to finish the wood components of the design.

6 Mechanism Design

6.1 Slider Crank Synthesis

The first step in designing the mechanisms for this project was deciding what size pizza the PizzaBot would be able to cut. The chosen pizza for this project was a thin crust frozen pizza purchased from Safeway with a diameter of 10.75 inches. To account for variations in crust size, the slicing mechanism was designed for personal pizzas with a maximum pizza diameter and cutting length of 11 inches.

To allow the pizza plate to rotate between slices, the slider retracts beyond the edge of the pizza plate on the return stroke. During this time it is suspended above the top platform and the wheel does not interfere with the pizza plate or edge guards, allowing the plate to rotate 60 degrees in preparation for the next cut. During design of the mechanism, the allowed rotation time (which occurs when the wheel is off the plate and within 2.5 inches of its minimum extension position) was found to be one third of the total cycle time, or 3.33 seconds when powered by a 6 RPM motor. This value was referenced when designing the geneva wheel to ensure the pizza plate has adequate time to rotate without interfering with the wheel.

The slider crank mechanism is a quick return mechanism with a ratio of extension to return time of 1.6. In prototype tests it was discovered that the pizza wheel did not consistently cut through the crust after a single pass. This led to the decision to pass the cutting wheel over the pizza twice before rotating the plate for the next slice. Because the second pass does not require as much cutting action, it can be faster without risk of the cutting wheel simply dragging over the pizza without cutting. Thus, a quick return mechanism was chosen to reduce the overall time per slice. As an added benefit, the final configuration allows a longer linear travel than an inline slider crank would. The vertical offset of 3.6 inches between the motor and track was chosen arbitrarily and checked via calculation to achieve a time ratio around 1.5.

The crank link has a length of 7 inches and the slider link has a length of 12 inches between pivots. The 12 inch long slider link was chosen to position the slider to the side of the rotation point at its minimum position.In the final configuration, the slider travels 15.1 inches linearly which maximizes the usable length of the 17.7 inch long track.

6.2 Geneva Wheel Synthesis

The geneva wheel mechanism was designed after the slider crank to accommodate the timing requirements of the first mechanism. The system was designed with a 7 inch diameter geneva wheel for stability of the pizza plate, and with six slots to generate six pizza slices. The pin diameter and clearance between the pin and slot were chosen to be $\frac{1}{4}$" and $\frac{1}{16}$," respectively. These dimensions were used to determine the radius of the geneva drive wheel, 2.021 inches. With a motor RPM matching that of the slider crank, this mechanism was confirmed using Matlab to rotate within the required 3.33 second window required by the slider crank.

7 Analysis

Velocity analysis was performed only on the slider crank mechanism. It was deemed unnecessary for the Geneva Wheel mechanism, as the drive wheel rotates at a fairly slow constant angular velocity of 6 RPM. When engaged, the angular velocity of the Geneva Wheel peaks at the same value. Velocity analysis of the slider was performed to confirm the its behavior as a quick return mechanism and check for any unwanted or too-abrupt behavior. As expected, the slider retracts (left side of the graph) faster than it extends. It reaches a peak velocity of 7 inches per second on the return stroke. This speed is not excessive and was not anticipated to cause the system any problems.

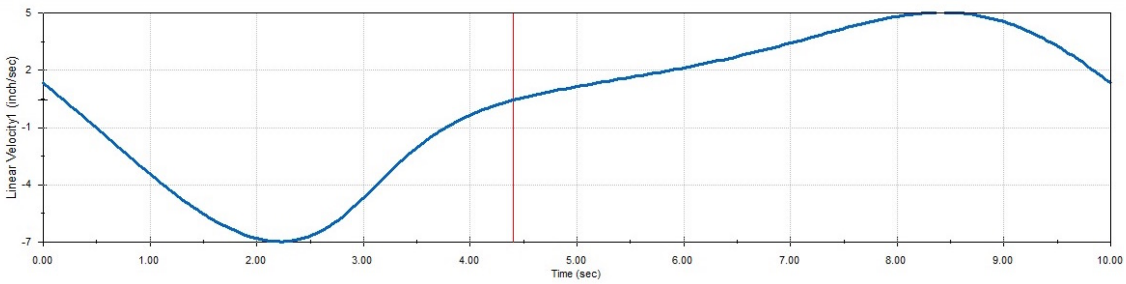


Figure 4: Plot of pizza wheel velocity over time (relative to the mechanism's starting extended position)

To find appropriate motors for this project, a motion analysis was performed to find the torque requirements for the slider crank motor. Prior testing showed that approximately 8 newtons of force applied to the pizza wheel horizontally was required to ensure consistent cutting through the pizza crust. A torque analysis from a Solidworks' Motion Analysis simulation with 10 newtons of force opposing the blade's movement produced the torque graph in Figure 4. The required motor torque peaks at 111 newton-inches during the wheel's return stroke. The chosen motors have a stall torque of 613 oz-inches, or 170 newton-inches. This provides a factor of safety of 1.5. In practice the maximum required torque is likely lower as the pizza will be cut nearly through on the wheel's advance stroke.

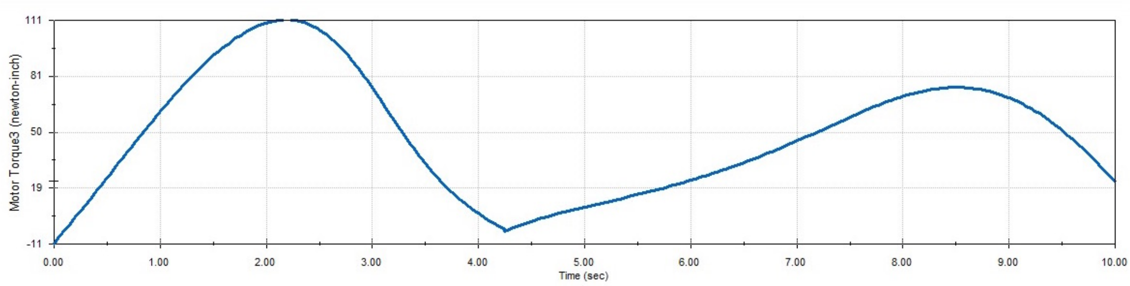


Figure 5: Plot of torque required from slider crank motor with time (relative to the mechanism's starting extended position).

7.1 Stiffness

The two rotating links of the slider crank and the connecting pin were identified as components most likely to deflect due to their relatively large length and because they transmit the largest magnitude torque produced by either mechanism. A Solidworks static simulation was performed to analyze deflection during the worst-case scenario of of the motor stalling. The simulation was performed with the mechanism in the orientation with maximum required torque found in the Motion Analysis study. A torque of 613 oz-inches was applied to the crank link around the axis aligning with the motor shaft. The pivot joints were constrained with fixed hinge constraints to allow the links to rotate about the radial bearing axis without deforming. Bearing contacts were selected for the three bearing locations, and the pin connecting the slider link to the slider was made rigid to simulate the motor stalling, unable to move the slider forward.

The simulation results revealed maximum deflection occurs in the crank link. However, the deflection is minimal, just over 0.01 millimeters. The slider link which experiences only tension and compression shows nearly zero deformation. This is not surprising; in the tested orientation with this link nearly perpendicular to the crank link, only twenty five pounds of force are applied in tension. Despite its small size and the relatively large force (for this mechanism) it experiences in shear, the connecting pin deforms less than one thousandth of a millimeter. Unlike the aluminum rotating links it is made of steel, a much stronger material.

Though deformation beyond that predicted by this simulation may occur in the actual model due to misalignment of shafts, poor tolerancing for bearings or spacing between rotating components, the links and connecting rod are certainly strong enough for this application.

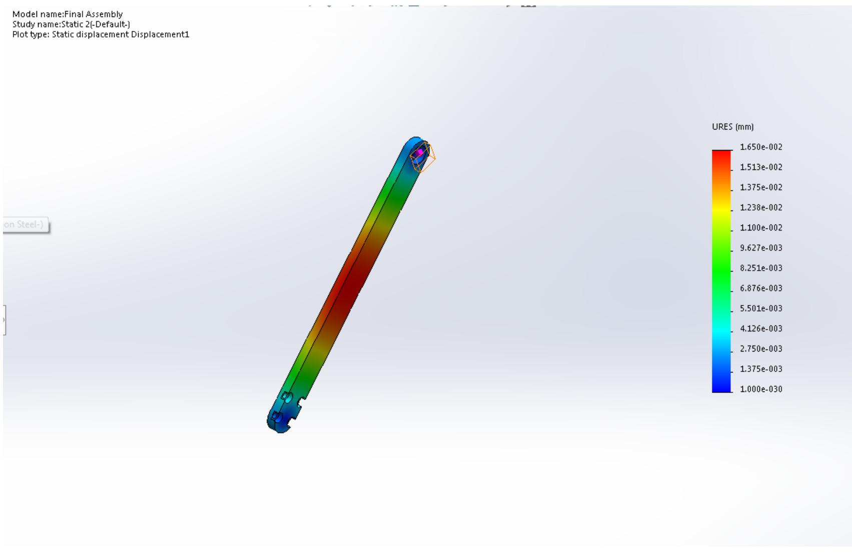


Figure 6: Solidworks deflection analysis of the crank link.

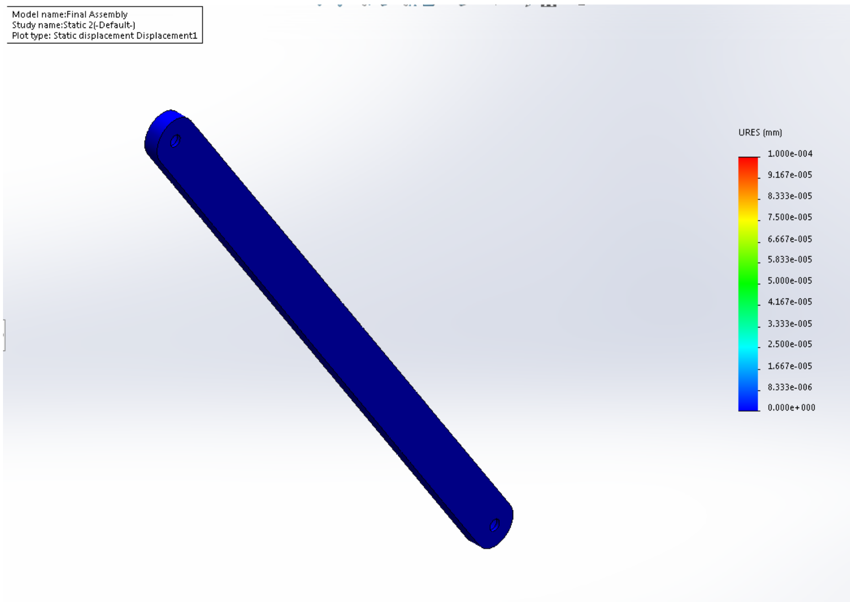


Figure 7: Solidworks deflection analysis of the slider link.

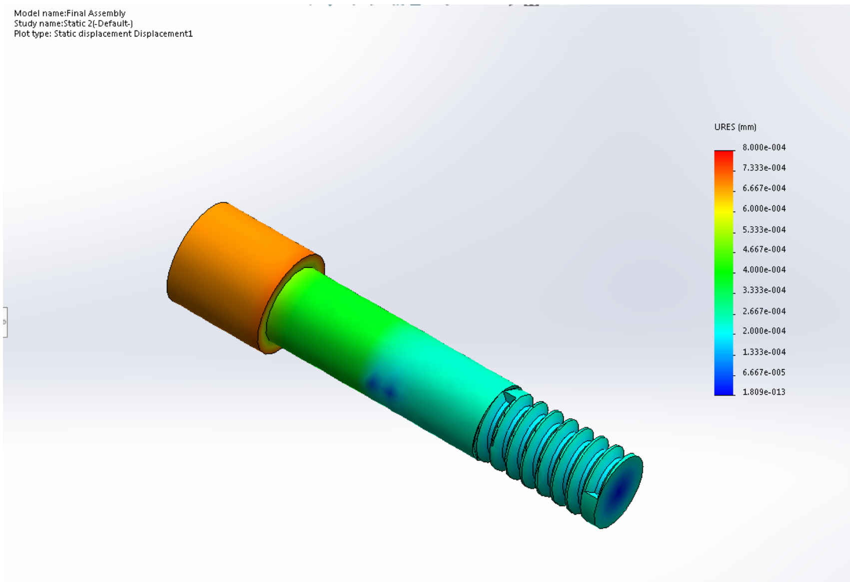


Figure 8: Solidworks deflection analysis of the connecting pin.

8 Assembly and Exploded Views

A rendered CAD model of the PizzaBot is shown in Figures 8. Exploded views of the slider crank and geneva mechanisms are also shown in Figure 9 and Figure 10, respectively.

9 Future Modifications

The prototype pizza bot has many modifications that can be made to improve future iterations of the product. One main improvement and addition to the product is the ability to put different size plates on the bot for different sized pizzas. The plate is already conveniently removable so to change the plate to a different size would be easy. One consequence of the addition would be the timing of the mechanism changing, as it is optimized for the exact size of the prototype pizza plate. This could be solved with a variable voltage system or other pre-programmed settings that would run the two motors at correct speeds to make the different pizza sizes cut successfully.

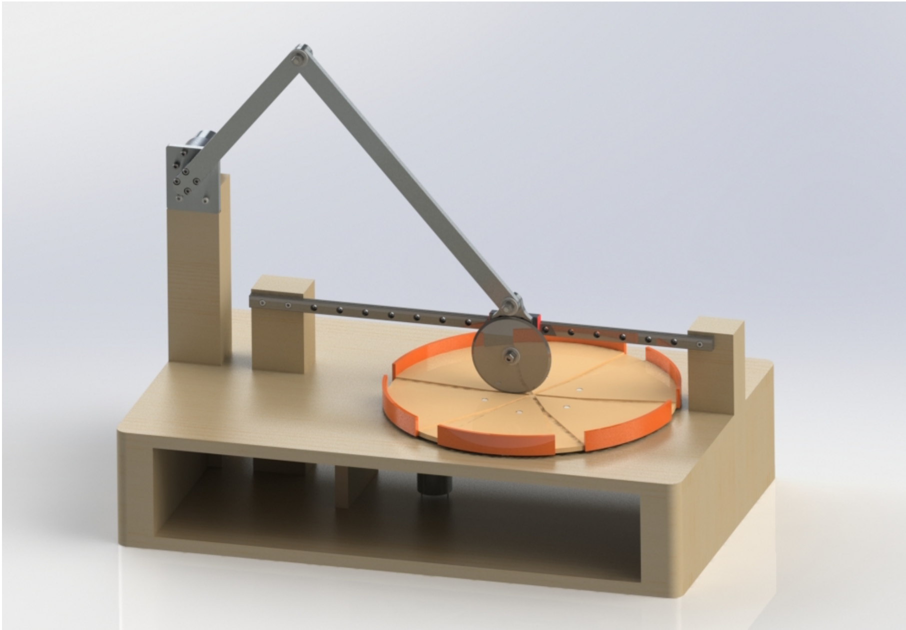


Figure 9: Solidworks render of the PizzaBot.

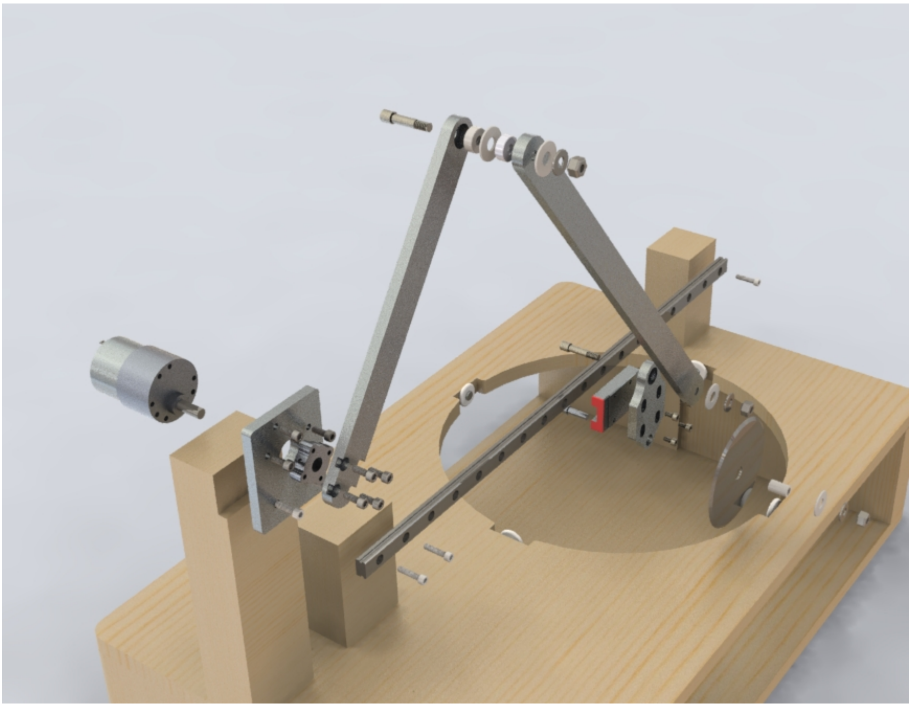


Figure 10: Solidworks exploded render of the slider crank mechanism.

Safety is always a concern when dealing with products that are dangerous and in an environment where children can be present. A safety case that encloses the device and blade while powered would nearly eliminate any danger from its use. The protective case could be designed in such a way that the motors cannot receive power unless the case is in place over the mechanism.

The PizzaBot, as it stands, runs continuously until the power is turned off by the attached switch. A useful addition to make the mechanism more user-friendly is the addition of an auto-off setting that turns the mechanism off after it has completed the necessary cuts. This would allow the user to perform other things while the cutting is taking place and turn the procedure into a one-step process.

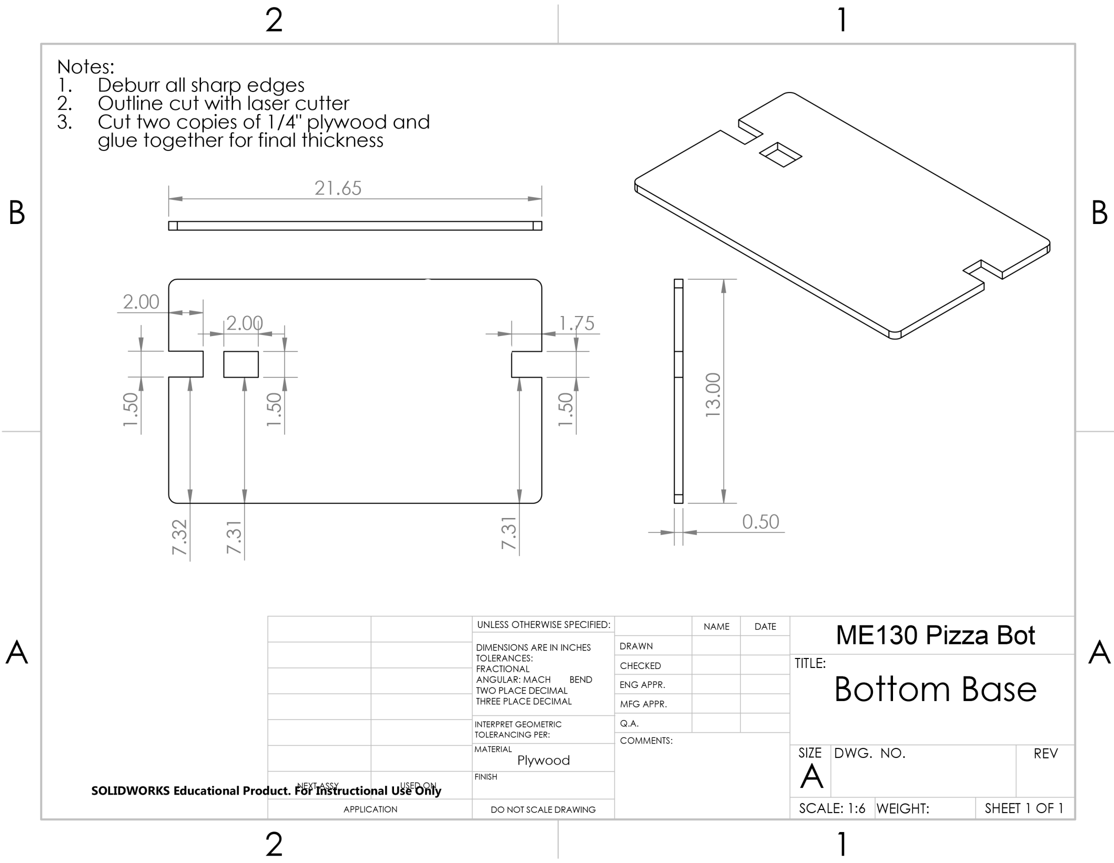
Another possible addition to the mechanism would be different attachments for differing food

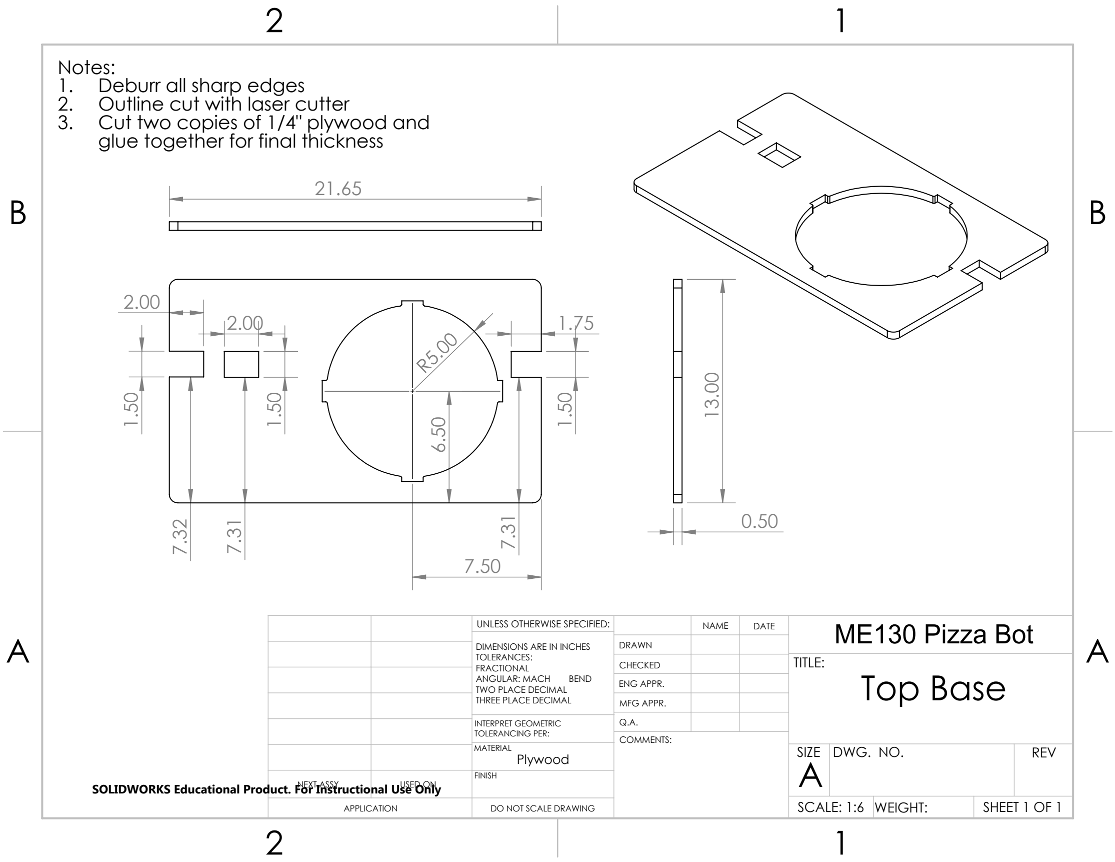
Figure 11: Solidworks exploded render of the geneva wheel mechanism.

or cutting choices. The blade is easily removed with a hex wrench but a more efficient clamp system could be used to switch between the pizza blade and other blades to cut things such as pies, cakes, sandwiches and other items.

Appendix

A 2D Shop Drawings

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3. Cut two copies of 1/4" plywood and glue together for final thickness
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2.00
1.75
R5.00
1.50
1.50
1.50
6.50
13.00
7.32
7.31
7.31
7.50
0.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Plywood
FINISH
NEXT ASSY
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ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ME130 Pizza Bot
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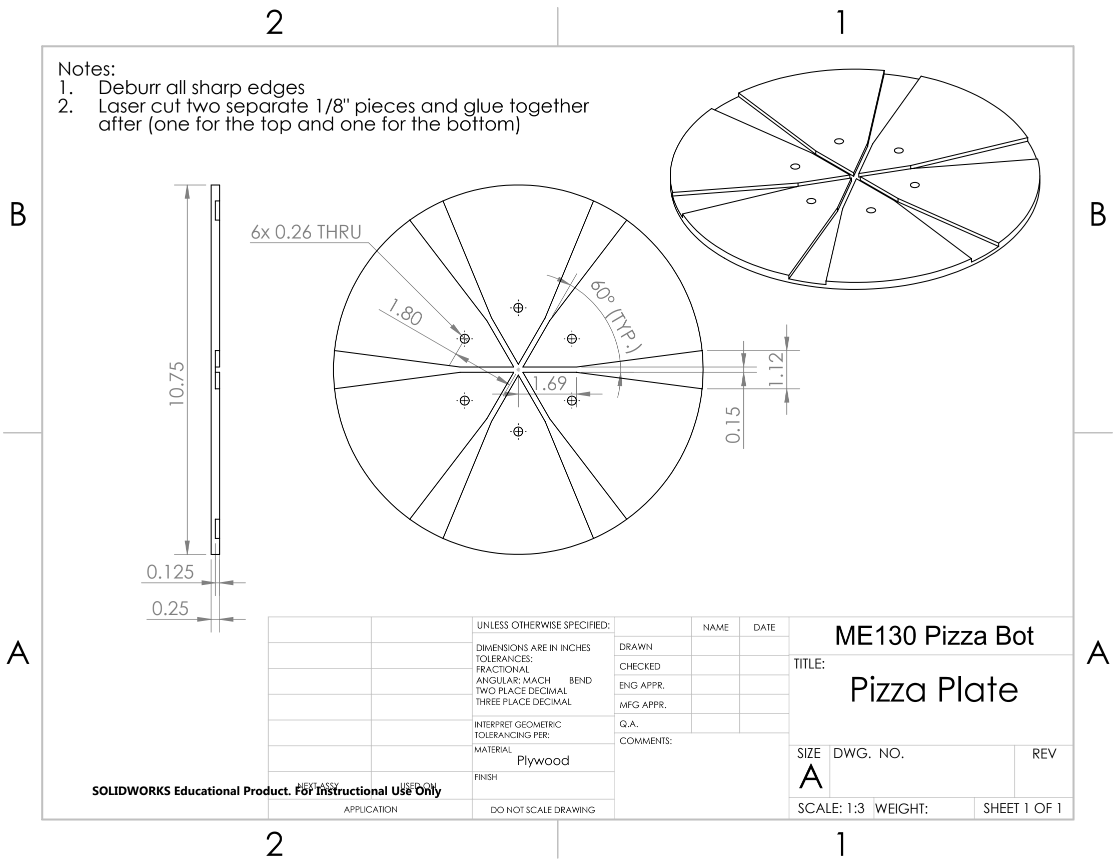
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only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2. Laser cut two separate 1/8" pieces and glue together after (one for the top and one for the bottom)
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DIMENSIONS ARE IN INCHES
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THREE PLACE DECIMAL
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MATERIAL
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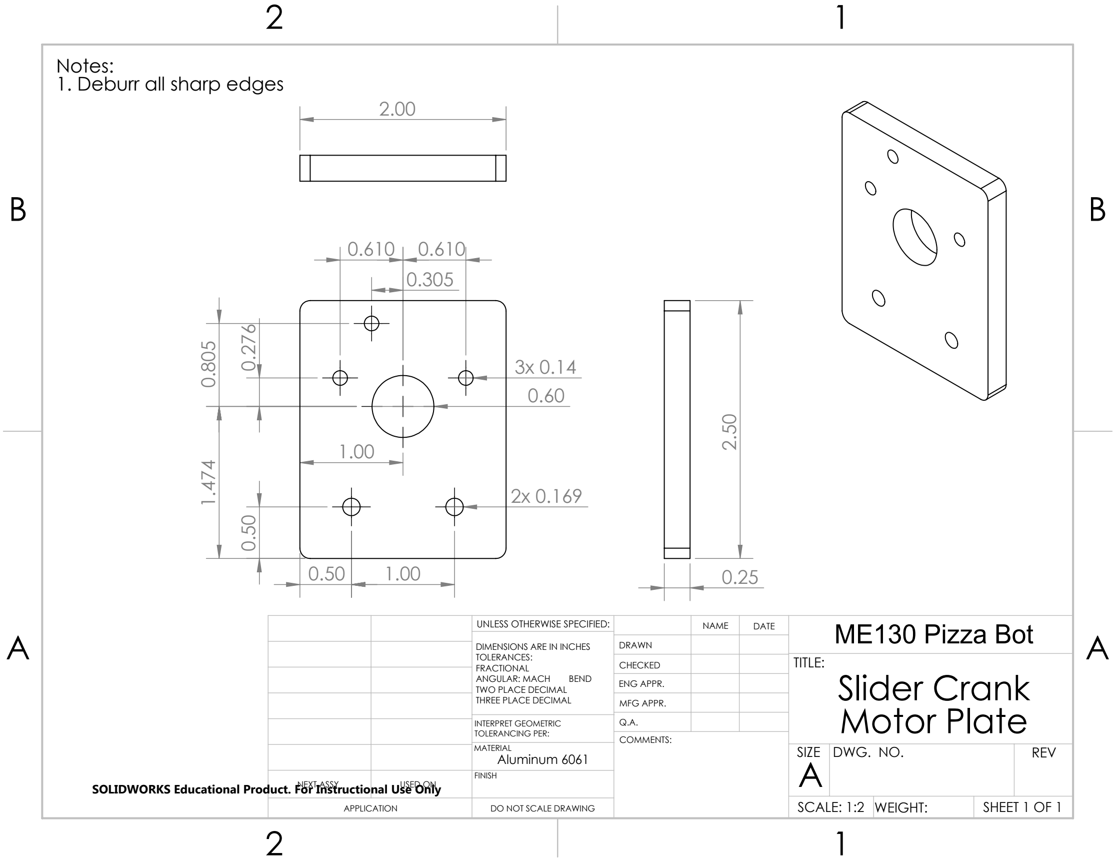
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2x 0.169
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0.50
1.00
2.50
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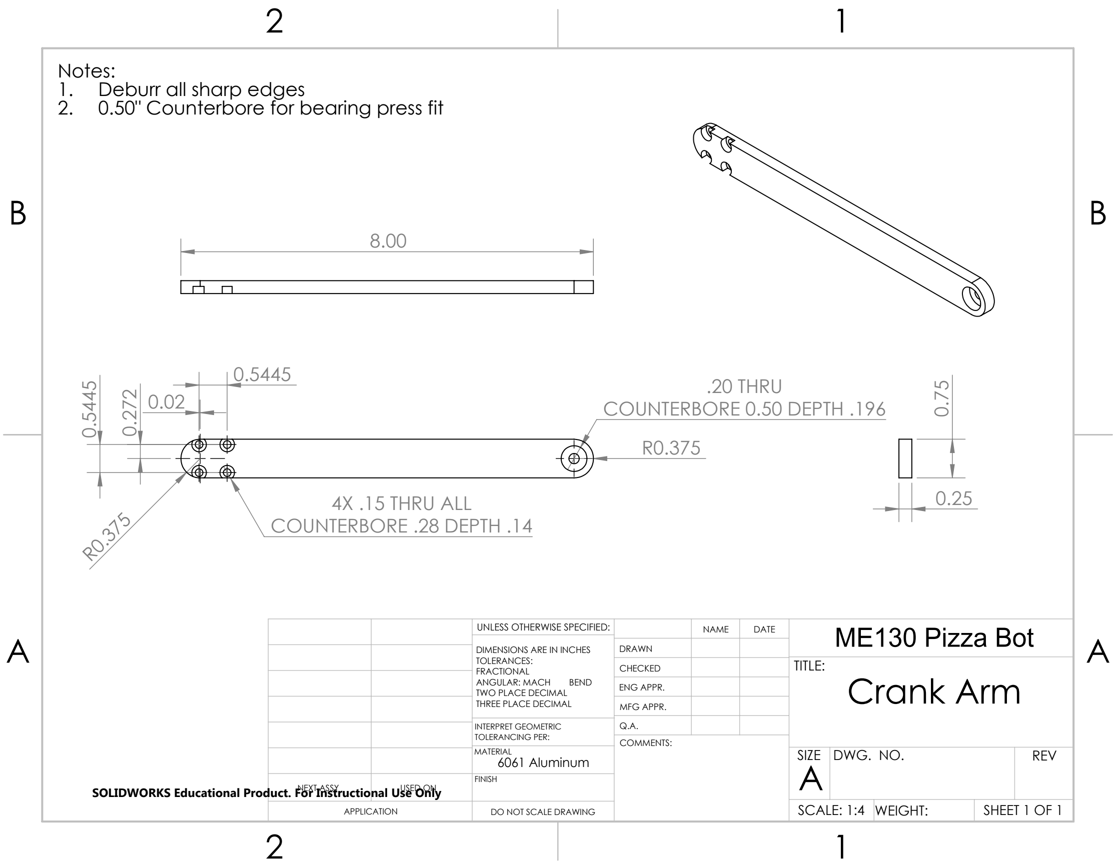
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COUNTERBORE 0.50 DEPTH .196
0.75
R0.375
4X .15 THRU ALL
COUNTERBORE .28 DEPTH .14
R0.375
0.25
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DIMENSIONS ARE IN INCHES
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FRACTIONAL
ANGULAR: MACH BEND
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THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
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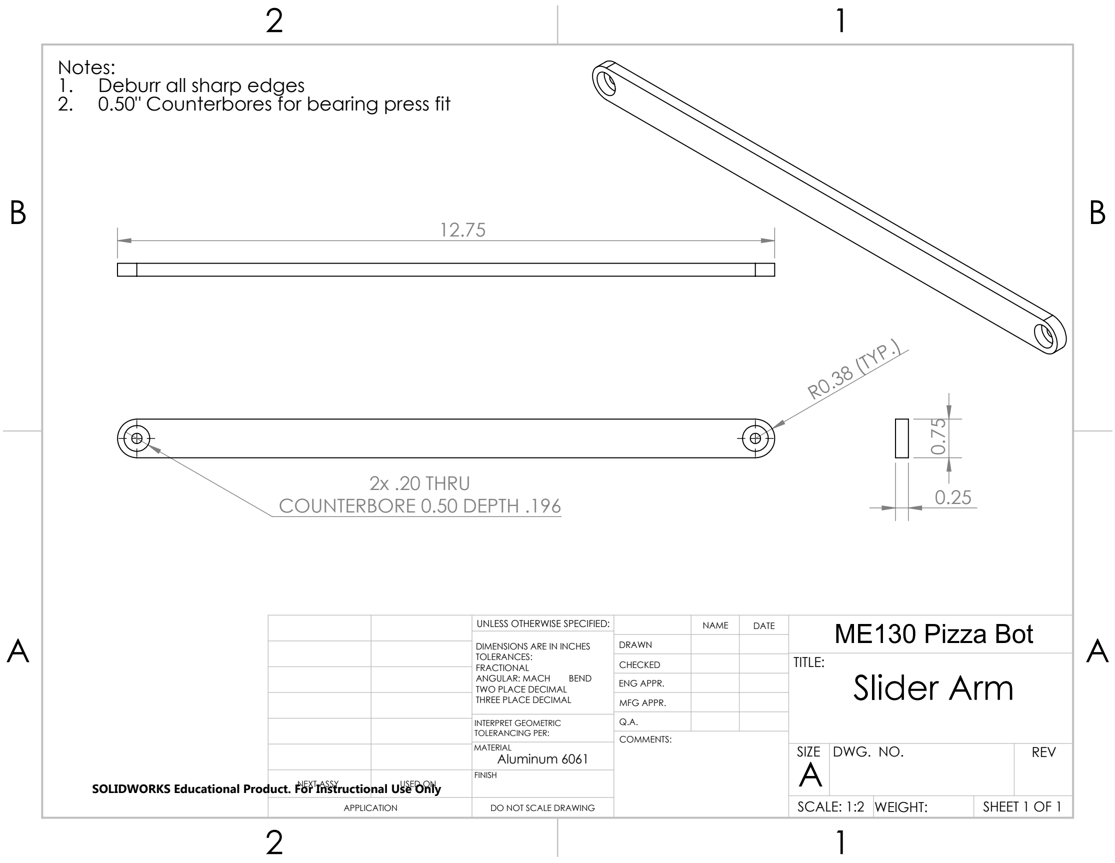
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0.75
0.25
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MATERIAL
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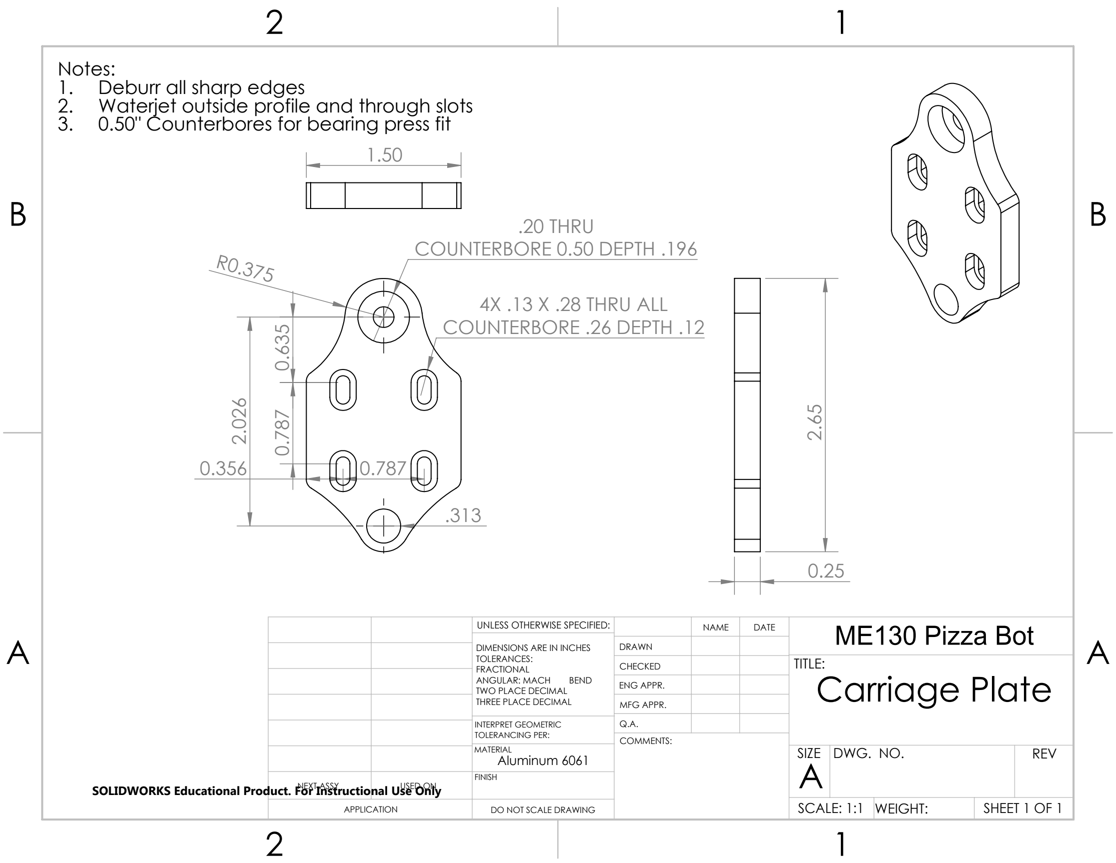
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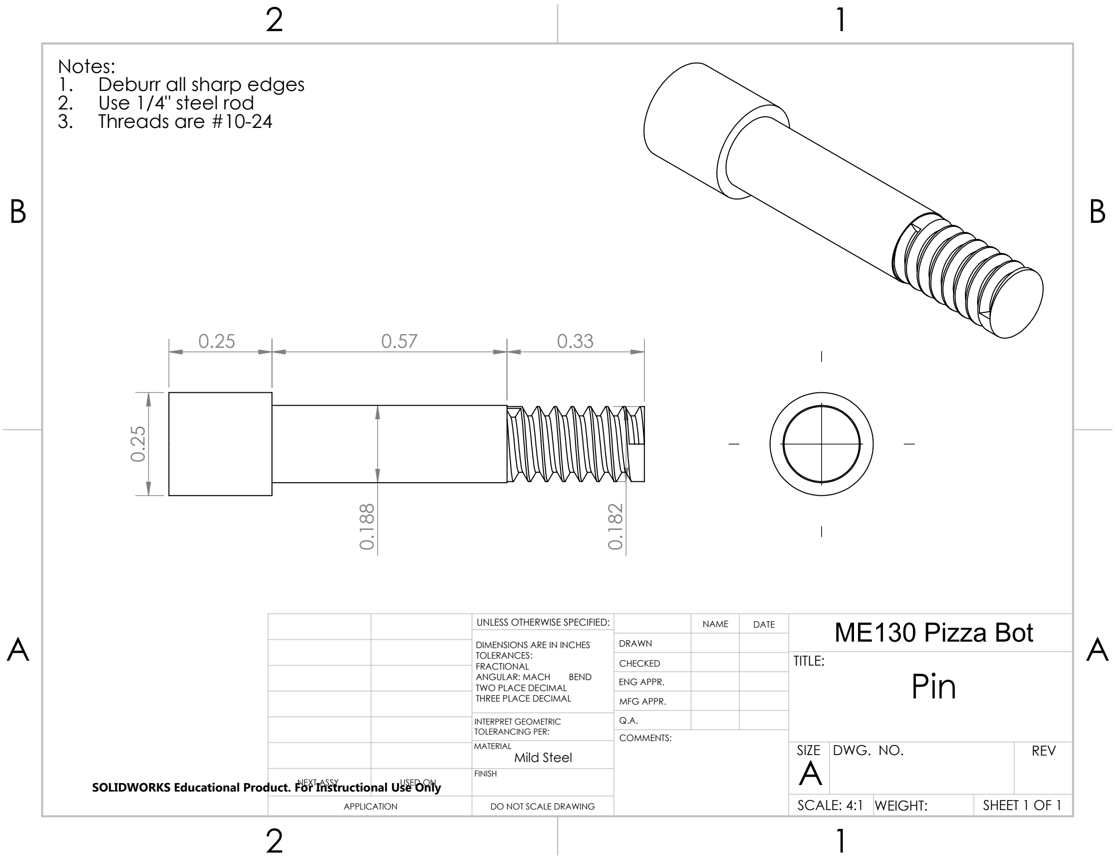
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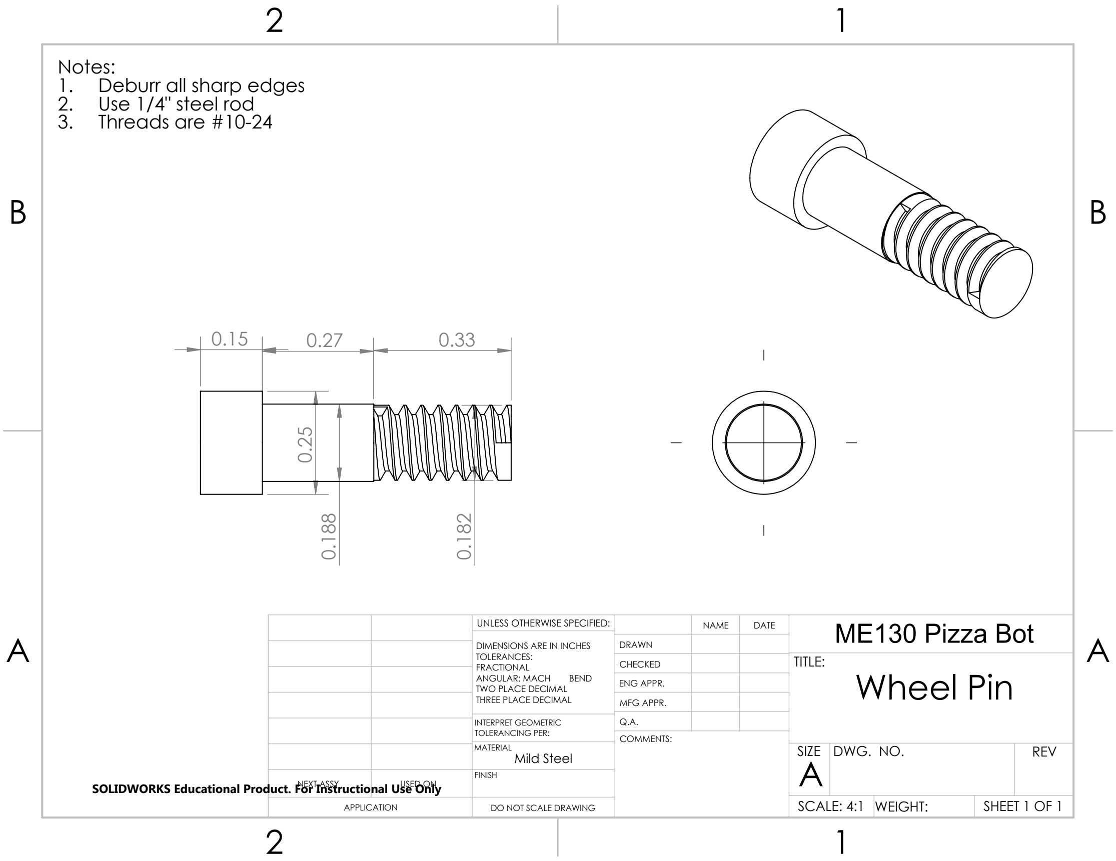
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ANGULAR: MACH BEND
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MATERIAL
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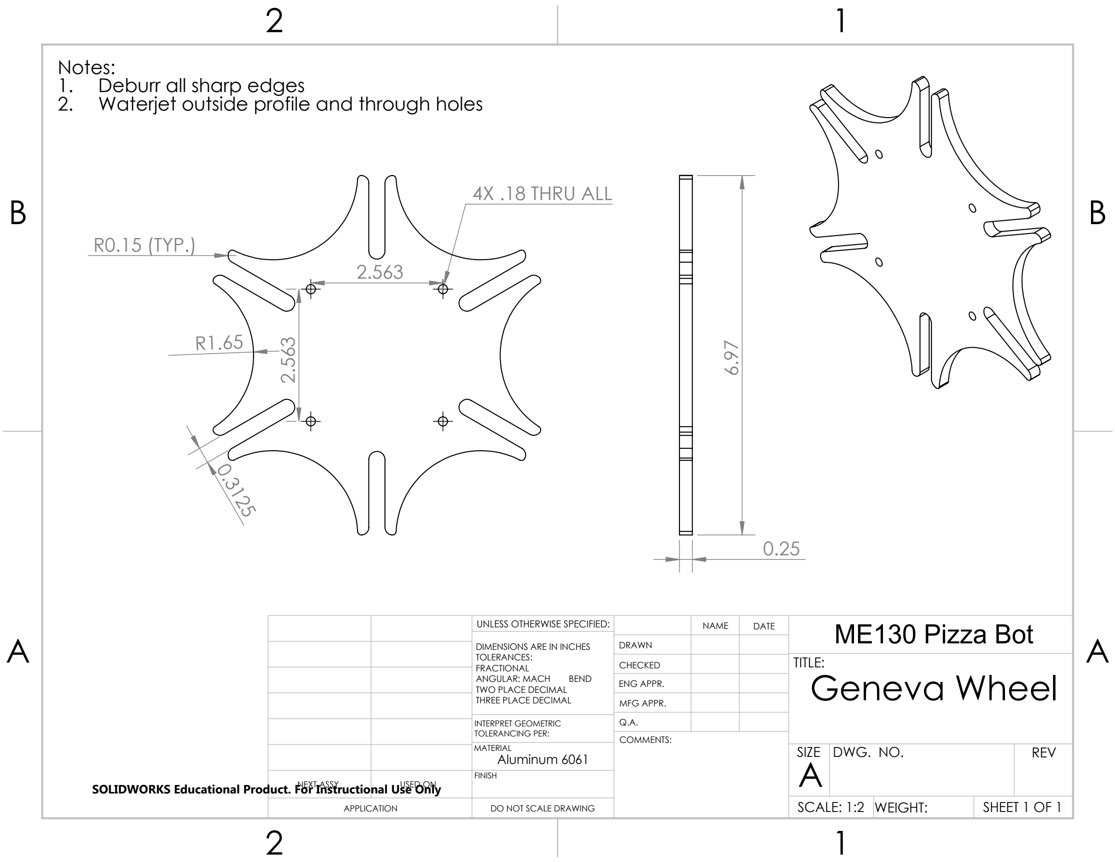
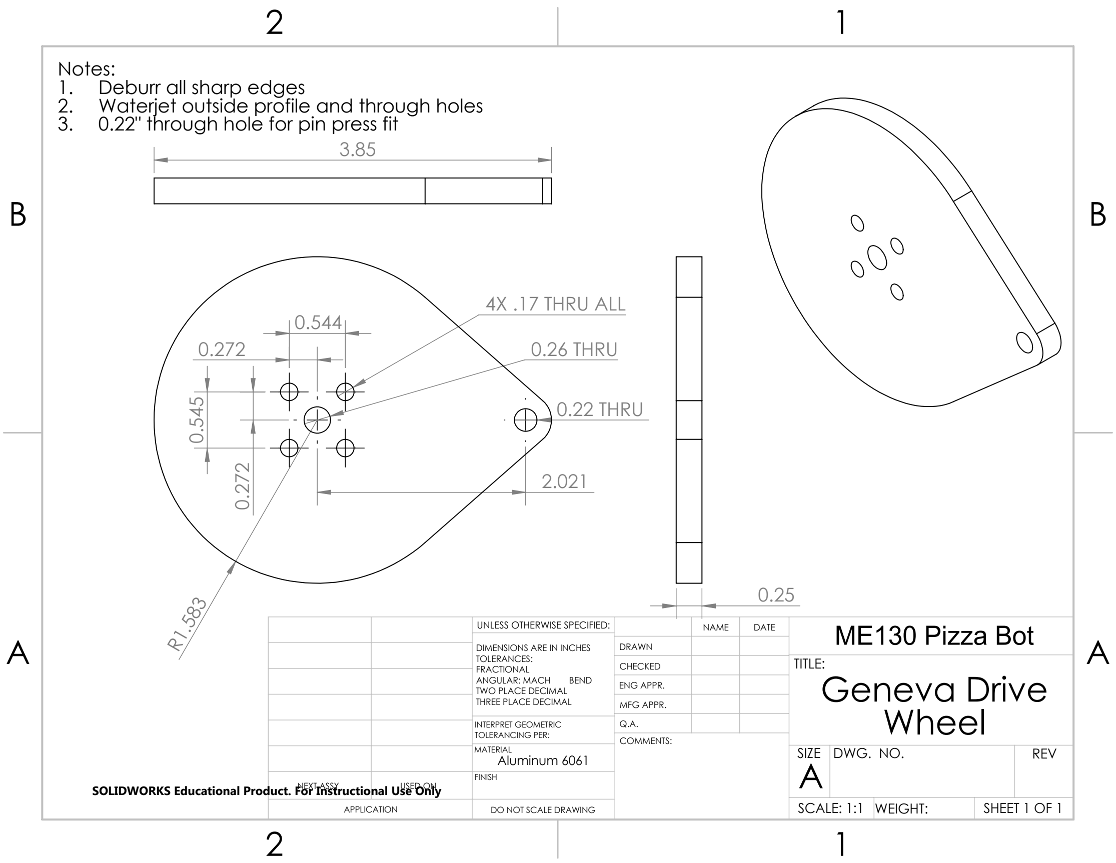
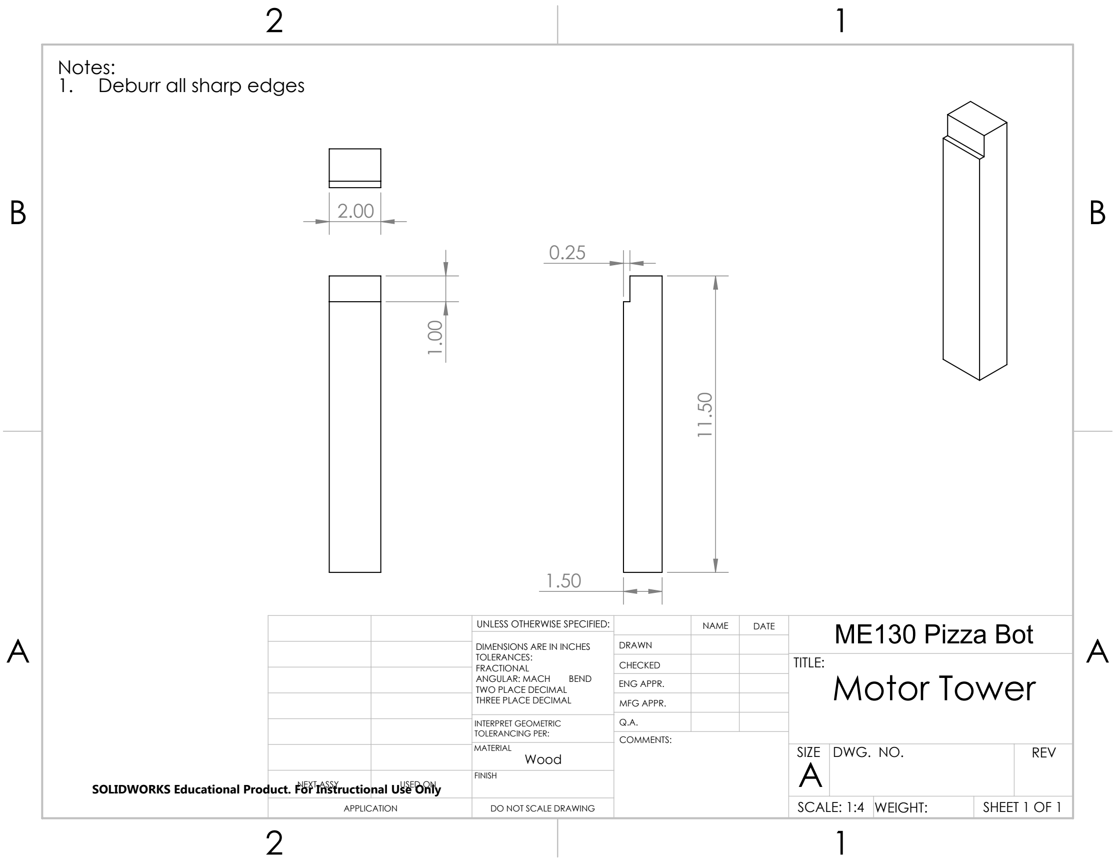
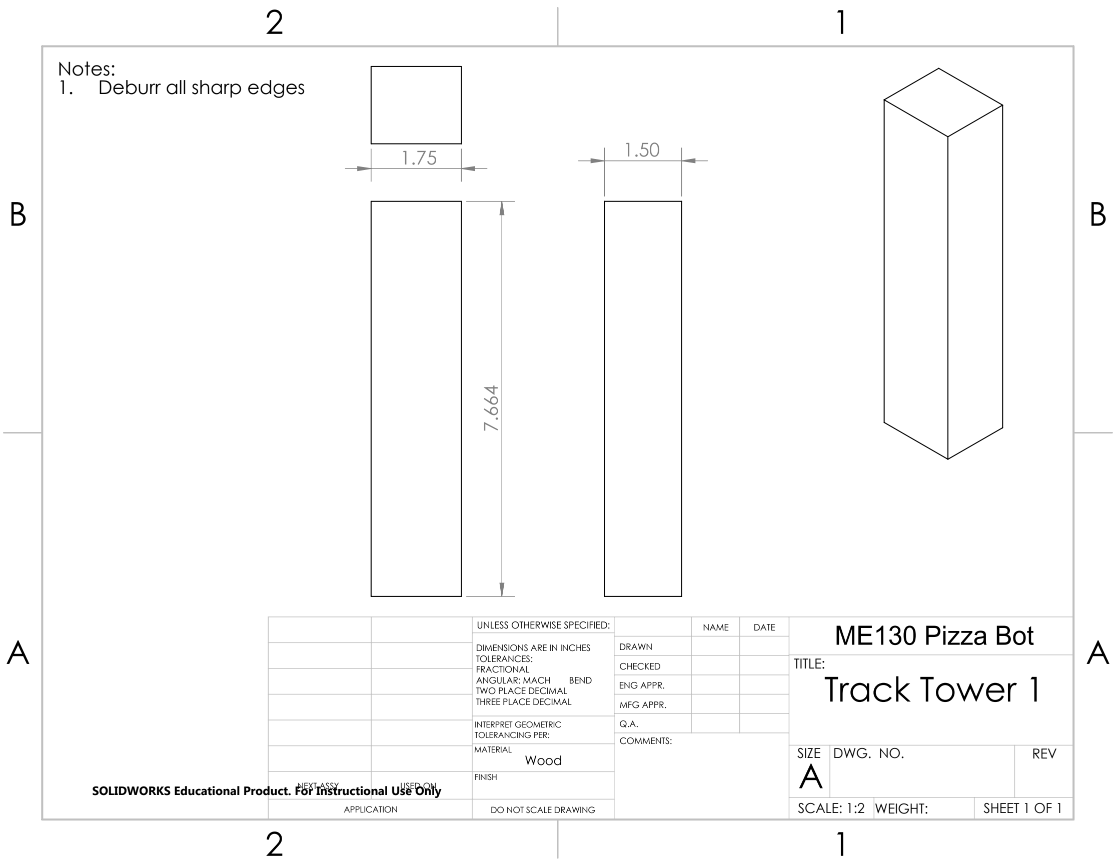
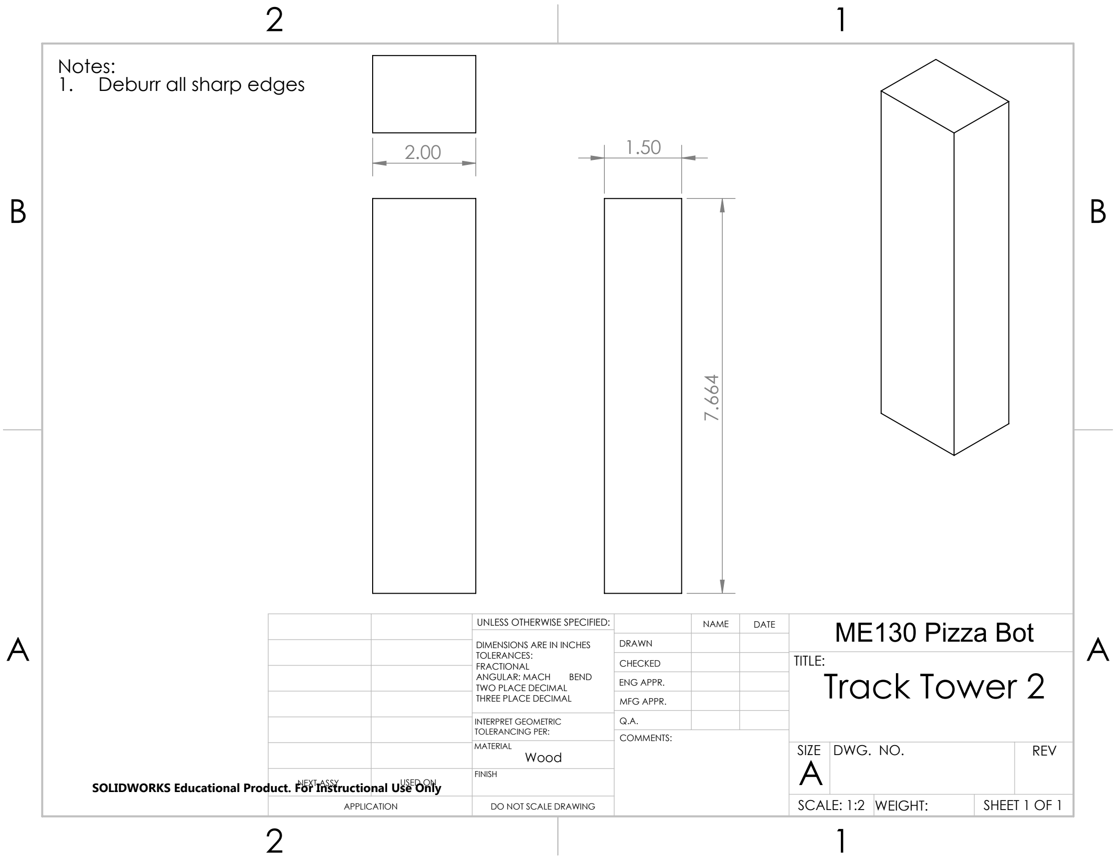
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only


Notes:
1. Deburr all sharp edges
2. Waterjet outside profile and through holes
4X .18 THRU ALL
R0.15 (TYP.)
2.563
R1.65
2.563
0.3125
6.97
0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum 6061
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ME130 Pizza Bot
TITLE:
Geneva Wheel
SIZE
A
DWG. NO.
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only


Notes:
1. Deburr all sharp edges
2. Waterjet outside profile and through holes
3. 0.22" through hole for pin press fit
3.85
4X .17 THRU ALL
0.544
0.272
0.26 THRU
0.22 THRU
0.545
0.272
2.021
R1.583
0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum 6061
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ME130 Pizza Bot
TITLE:
Geneva Drive Wheel
SIZE
A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only


Notes:
1. Deburr all sharp edges
2.00
1.00
0.25
11.50
1.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ME130 Pizza Bot
TITLE:
Motor Tower
SIZE
A
DWG. NO.
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only


Notes:
1. Deburr all sharp edges
1.75
1.50
7.664
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ME130 Pizza Bot
TITLE:
Track Tower 1
SIZE
A
DWG. NO.
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only


2
1
B
A
Notes:
1. Deburr all sharp edges
2.00
1.50
7.664
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
Wood
FINISH
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ME130 Pizza Bot
TITLE:
Track Tower 2
SIZE
A
DWG. NO.
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
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B Bill of Materials

Part	Quantity	Cost per unit	Total Cost
6 RPM Gearmotor	2	$24.99	$49.98
Set Screw Motor Hub - 6mm Bore	2	$4.99	$9.98
3” Square Lazy Susan Bearing	1	$2.18	$2.18
8”x8”x1/4” 6061 Aluminum Sheet (for Geneva Wheel)	1	$14.80	$14.80
6”x8”x1/4” 6061 Aluminum Sheet (for Geneva Drive Wheel, Motor Support Plate and Carriage Plate)	1	$11.40	$11.40
18”x30”x1/4” Plywood (for Top Base, Bottom Base, Geneva Platform and Pizza Plate)	4	$3	$12
Miniature Linear Guide Rail (450mm length) and Ball Bearing Carriage Block	1	$31.99	$31.99
¾” Tub Enclosure Rollers (4 pack)	1	$3.07	$3.07
Double Sealed Ball Bearing (½” OD, 3/16” ID)	4	$3.12	$12.48
Nylon Dry Running Sleeve Bearing (3/16” ID)	1	$0.65	$0.65
Low Carbon Steel Rod (¼” diameter, 12” length)	1	$1.04	$1.04
¾”x24”x1/4” 6061 Aluminum Bar (for Slider Crank Links)	1	$1.96	$1.96
2”x4”x8’ Construction Lumber (for Base supports)	1	0	0
1½” Cabinet Screws	40	0	0
M3x25mm Socket Head bolts	3	0	0
M3x12mm Socket Head bolts	8	0	0
M3x6mm Socket Head bolts	4	0	0
6-32x1/2” Socket Head bolts	8	0	0
8-32x3/4” Pan Head bolts	8	0	0
8-32 Nuts	8	0	0
10-24 Nuts	3	0	0
3/16” Flat Washers	7	0	0
¼” Nylon Washers	8	0	0
2 Pole Switch	1	0	0
3 Pole Switch	1	0	0

References

[1] Norton, Robert L. Design of Machinery. Third ed. N.p.: McGraw-Hill College, 2007. Print.

[2] Johnson, J. E. "Make Geneva Wheels of Any Size." New Gottland. N.p., 08 Jan. 2012. Web. 08 Dec. 2016.

[3] Youssefi, Ken. "Graphical Synthesis." Mechanical Engineering 130. University of California, Berkeley. Oct. 2016.