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CPSC 1091: Engineering Design and Drafting

Final Report

Project #	1	Date	November 20, 2020

Project Title	Wheelchair Collapsible Cup Holder
Client Name	Tetra Society
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Tetra Society of North America

Executive Summary

Tetra society of North America is a not-for-profit organization where engineers volunteer to construct custom assistive devices for disabilities.

Wheelchair users often have hand disabilities and operating the wheelchair is an arduous task when they hold a cup. Tetra society is in need of a cup holder design for left-handed wheelchair users (of the Quickie S-646 model) that moves the drink to different positions about the wheelchair, holds cups of different sizes, is collapsible to avoid taking up unnecessary space, and allows complete maneuverability through doors and hallways.

The primary functionality of this cupholder was determined by the team to be as follows:

- Holds the drink in place
- Moves the drink to different angles
- Holds cups of different sizes

The key objectives for the design were determined to be accessibility, expandability, stability, and collapsibility. The constraints for the design were determined by relevant documentation from the Quickie S-646 parts manual and the British Columbia Building Code. These constraints were imposed with respect to Quickie S-646 and doorway/hallway dimensions.

Essentially, the design process was broken down into two key components: the cupholder and the attachment to the wheelchair. Initial designs for the attachment involved utilizing flex metals, however, these ideas were disregarded due to the unpredictability of the mechanisms involved and were replaced with ideas regarding rails. With reference to sliders used in cinematography, a single rail concept (connected to the wheelchair using clamps) was decided upon due to superior stability and accessibility. A double rail idea was proposed but rejected due to unforeseen complications. Moreover, the collapsible cup holder design was selected with reference to in-market commercial models. Also, after thorough analysis, a gyroscope function was also added due to the obvious increase in stability of the design.

This design was implemented based on metrics associated with the determined objectives (these metrics were parameterized according to the relevant codes/standards of in-market commercial products.) The team then developed a test plan in regard to these objective metrics and tested a prototype of the design.

Implementation requirements were listed for the client to ensure appropriate procurement of necessary resources (including workforce and materials). Materials of the design were determined to be alloyed steel for the main body, carbon steel for the fasteners and rubber for the wheels. The life cycle assessment highlighted the manufacturing process of the materials, machining time for the parts, transportation time for the final product, and end of life information regarding recyclability and waste. Economic and sustainability reports were created using the Solidworks application to support the data in the design report.

Tetra Society of North America

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1.0 Problem Statement

The client Tetra society is asking volunteer engineers to design and construct custom assistive devices for people with disabilities. In this project, the client needs a cup holder for left-handed wheelchair users of the Quickie S-646 model. Since wheelchair users often have difficulty operating their wheelchair and handling a drink at the same time, the proposed design of the cup holder should grant the user the freedom they need.

1.1 Client Requirements

The client requires that the cup holder

a. Needs to be designed for left-handed use
b. Needs to be usable from different angles
c. Needs to hold various cup sizes
d. Needs to be collapsible (when not in use)
e. Needs to allow passage through doorways

1.2 Functions

The functional basis of this design is to hold a cup. Consequently, the design performs the following functions:

- Holds drink in place
- Holds cups of different sizes
- Moves the cup to different places

1.3 Objectives

Table 1. Objectives and objective goals

Objective	Goal
Accessibility	a. Should always be able to move to various locations parallel to the left arm rest and within arm's reach. b. Should be able to operate with only the left hand after installation.

Expandability	c. Should be able to hold cup sizes ranging from diameters of 7 cm to 9 cm [Appendix B]
Stability	d. Should be able to hold the drink at angles of inclination/declination up to 30 degrees. [Appendix C]
Collapsibility	e. Should be able to collapse to 25% of protrusion [Appendix D]

1.4 Constraints

The following constraints are set by taking into consideration the Quickie S-656 parts manual and other documentation as indicated.

Constraints imposed by client follow:

a. Must not restrict functionality of the Quickie S-656 wheelchair - notably the Dual post Height Adjustable Flip Back Armrest [1]

Constraints imposed by regulations follow:

b. Must not exceed total width (including the width of the wheelchair) of 810 mm [2]

2.0 Detailed Design

The cup-holder design process included a number of cycles of coming up with ideas, implementing and then rethinking. The central idea of having a cup-holder mechanism (with the gyro) connected to a base was established, and the idea was to somehow hold the cupholder in place, but a number of issues had to be addressed:

a. How will the cupholder collapse, exactly?
b. How will the cupholder be held in the precise horizontal position with enough stability to hold the weight of a cup?
c. How will the collapsibility integrate with a support piece?
d. How will the support system activate automatically with the opening of the cup-holder?
e. How will the cupholder accommodate a range or cups with different radii (upper radii and lower radii)?

The design addresses all of these questions. The idea of using torsion springs to activate the support automatically was implemented, the dimensions of all of the pieces

accommodate this system so that, in the end, the customer can pull up the cupholder from the vertical position to the horizontal position and expect it to stay up. Additionally, the cup-holder collapses with a simple push on the support piece. In order to be able to use many different sizes of cups with this product, two decisions were made. First, we decided to implement thin flaps in the inner radius of the cupholder. This provides friction and stability to different sizes of cups. In addition, the cups themselves are supported from the bottom with a net that is attached to the cupholder, in case the flaps don't provide enough friction to accommodate the weight of the cup that is being used.

We addressed the rail car design from two different aspects: the connection to the rail and the attachment to the cupholder.

Regarding the connection to the rail, it originally included a four-wheel system to enhance the overall stability. Ultimately, a two-wheel system was chosen as a four-wheel system was anticipated to cause issues on the rail's L turn. The axles holding the wheels were envisioned similar to a stud bar to enable proper placement of the wheels; however, the axles' small dimensions relative to the wheel were foreseen to be an issue.

To deal with the size issues, smooth axles were chosen. A smooth axle allows for the use of costume sized rubber pieces to be placed on either side of the wheels to lock their positions. The rubber will stay in place thanks to the rubbers' high friction coefficient. The rubber will also add to the stability of the system thanks to its vibration absorption qualities.

Regarding the connection to the cup holder, The design required the rail car to be extended. This was done so the cupholder does not come in contact with the handle of the wheelchair. As well, to avoid unnecessarily adding to the footprint of the wheelchair and cause issues of accessibility while passing through tight spaces, the dimension of the extension was chosen so the cup holder will be adjacent to the handlebar.

The rail car's extension was first envisioned as either a block-like design or, similar to stud placements in construction, an X-shaped connection to ensure stability. The X shaped and block designs were found to hinder the assembly process. In the end, a triangular shape was used to ease the process of attachment to the cupholder. Although not as strong as an X shaped extension, the triangular extension is strong enough to hold drinks of various weights.

Regarding the wheels, a symbiotic approach with the rail design was needed to create an efficient and stable system. We looked into several configurations, and ultimately, to accommodate the L-shaped turn on the rail, wheels with inward angled indents were chosen. We found that a greater angle on one end of the wheel will allow for free movement on the turn while providing maximum stability.

The design process for the rail began with the idea that the cross sectional view of the rail would be rectangular, and the rail would uniformly curve around the arm of the wheelchair into a shape resembling an L. The cross sectional view of the rail was changed to represent a diamond shape along the top and bottom of the rail. This diamond shape was implemented to allow the wheel to easily sit on top of the rail without worry of falling or

sliding off. Also the sharp top and bottom edges of the rail more smoothly guide the movement of the railcar on the rail. The second change to the rail was to implement both the front and back clamp into the rail. To achieve this, two short arms with semicircle clamps on the ends were added to the vertical edge of the rail where the rail will connect to the wheelchairs frame. The arms for these clamps are vertically central to the rail so that they do not interfere with the path of the railcar and wheels. The complimentary semicircle clamps are made separately and attached via screws to achieve strong attachment to the wheelchair frame. Thirdly, the cross-sectional view of the rail along the bend was changed so that the wheels could negotiate the curve. The change in rail was achieved by simply cutting the cross-sectional view of the rail in half vertically and keeping only the side of the rail that faced outward along the curve. This achieved a flat curved side facing the inside of the curve. Finally, to strengthen the curved section of the rail, a horizontal support piece was added to the rail. Similar to the clamp arms, this support piece is vertically central as not to interfere with the path of the railcar and wheels.

For the design process of the catch blocks, the original design was to have a rectangular prism shape with the area of the rail extruded completely through and two small circles extruded halfway through for magnets. The only change in the catch blocks came to extrude part of the block so that the catch blocks can slide past the clamp arms. The rear catch block needs to be able to slide so that the user can have their cup in the most comfortable position.

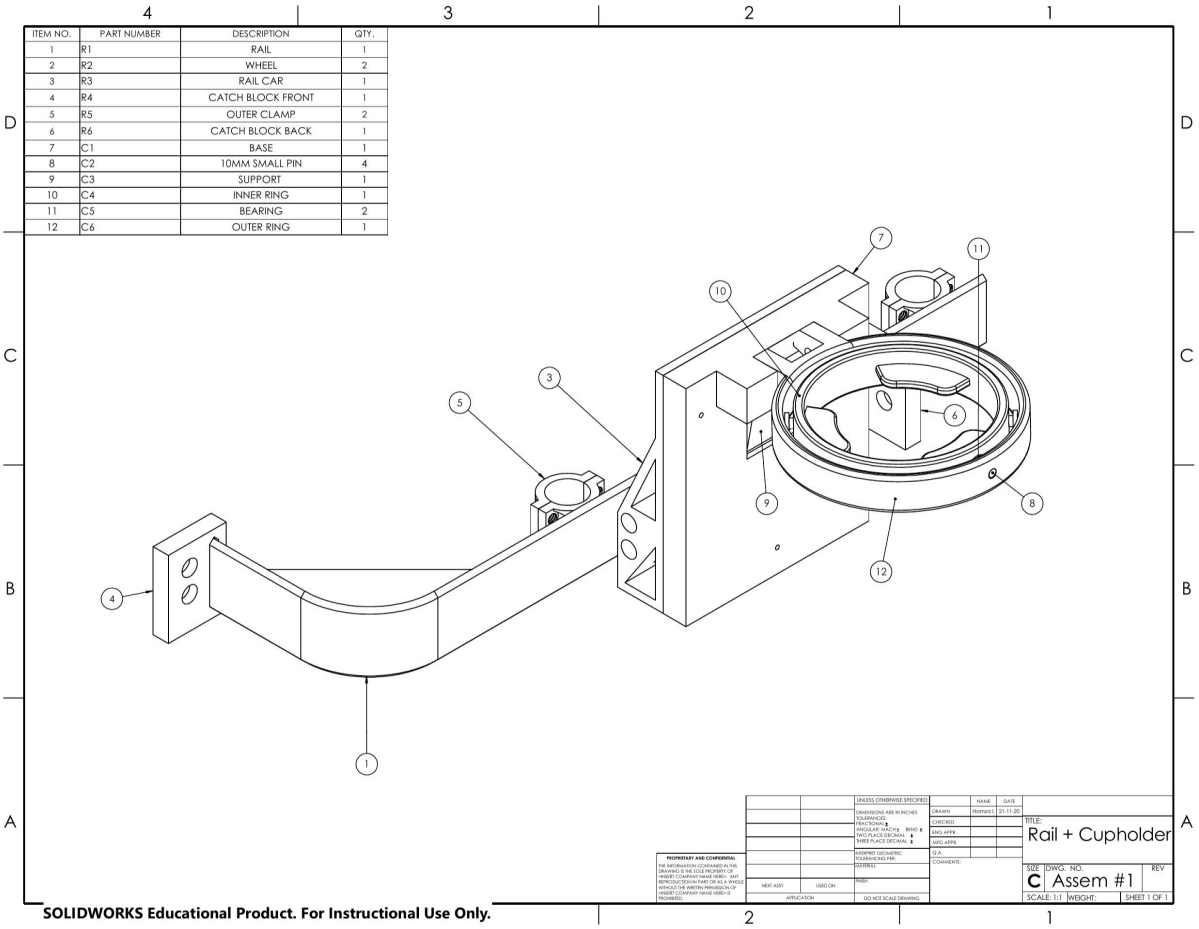

Figure 2.0.0.1: Rail + Cupholder

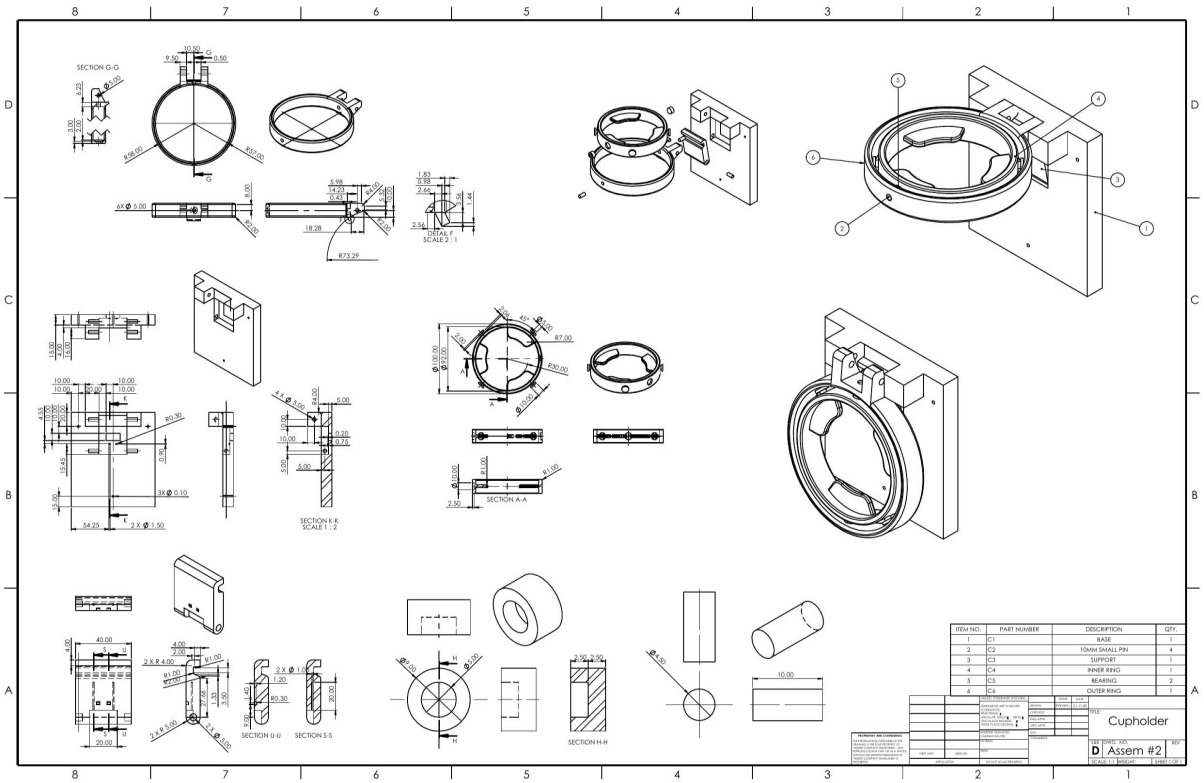

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Figure 2.0.0.2: Cupholder

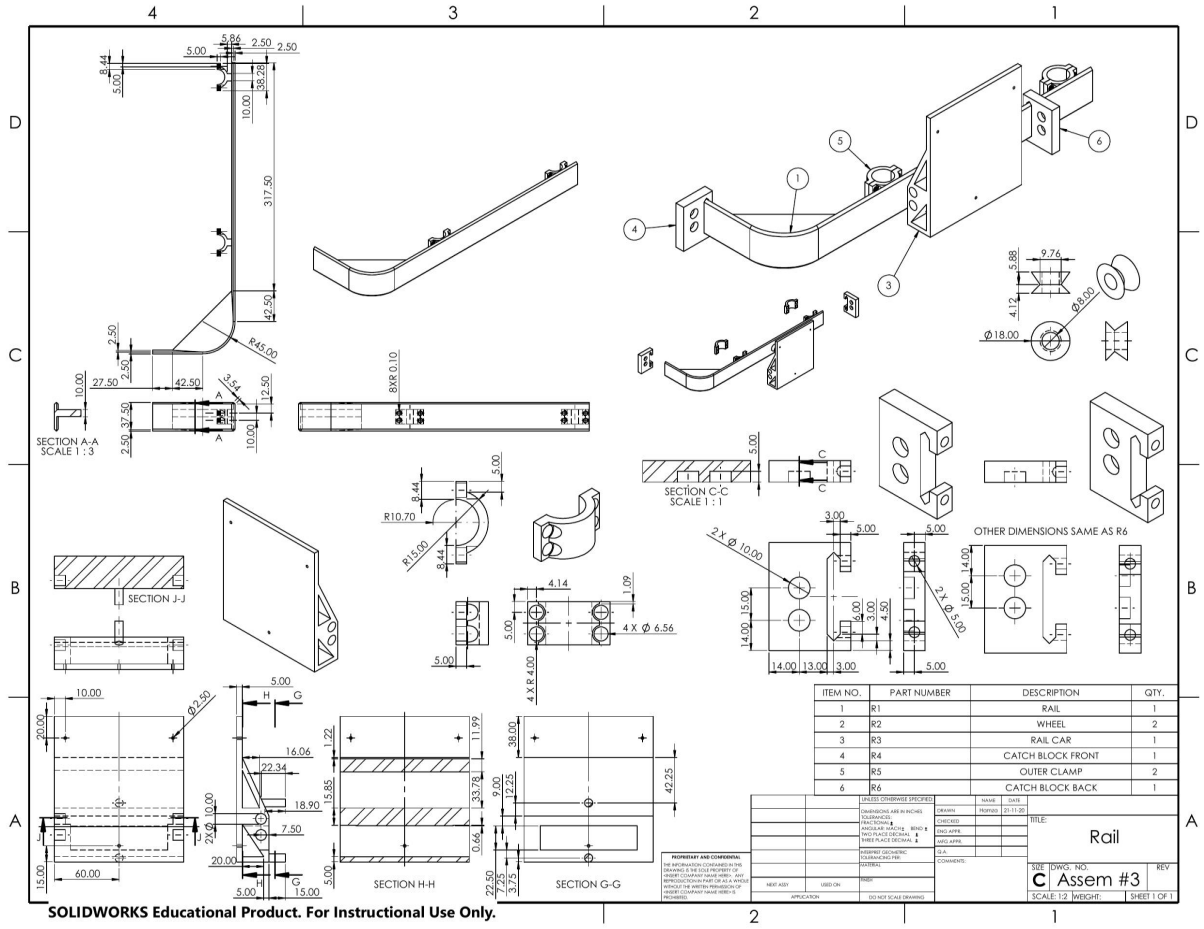


Figure 2.0.0.3: Rail

2.0.1 Base, Support and Gyro mechanism Description

2.0.1.1 Base: The “base” piece is the foundation of the cupholder. It connects to the rail-car with 3 screws, triangularly positioned to provide maximum stability. The front side of the base has a cut section to house a support piece, which is connected to the base with two pins. There are two small rings in this space to facilitate springs pins from the “automatic opening mechanism” (see later 2.1.4). The top of the base includes the connection to the cup-holder with two pins that allow the cupholder to rotate on its axis (to open, and to collapse down). The range of rotation is from the horizontal position to the vertical position, when it aligns with the base.

2.0.1.2 Support: The support piece fits into the space cut out of the front of the base with two pins. It can rotate with a range from the horizontal position downwards. A mechanism on the outer ring will limit this rotation to hold up the cup-holder.

The height of the support was calculated so that once inclined to the correct angle it holds the cupholder in the perfectly horizontal position. In the front view of the support there is a cut space to house the outer ring extrusion.

2.0.1.3 Cup-holder: The cup holder is designed to accommodate a variety of cup sizes and uses a gyro mechanism to provide stability when the wheelchair goes into an incline.

2.0.1.3.1 Outer Ring: The outer ring is connected to the base with two pins that allow it to rotate. This is the collapsibility mechanism. The ring has two holes opposite each other that house pins to go through into bearings that hold the inner ring in place and allows for free rotation in one plane. Since the support piece's height reaches above the bottom of the outer ring, the bottom of the section of the outer ring that connects to the base was designed specifically to allow the full range of motion of the support piece to open.

2.0.1.3.2 Inner Ring: The inner ring is held in place by two bearings in its outer radius that are held in place by the two pins coming from the outer ring. This allows the inner ring to rotate in one plane. The outside radius of the inner ring has 4 buttons separated by 90 degrees that are meant to hold a net. The inner radius of the inner ring has three flexible thin flaps that provide different amounts of friction for cups of various radii and weight. These flaps contribute to the stability of the cups themselves when they sit inside the cupholder acting as shock absorbers.

2.0.1.4 Automatic Opening Mechanism: two torsion springs are anchored on one side to the base and held on the other in the support (one end of each spring fits inside small vertical holes in the support). When the mechanism is closed, the springs' tendency to return to natural state applies a force to open the support outwards towards equilibrium (natural state), thus propping up the cupholder. When we want to fold in the cupholder, we press in the support inwards toward the base. Once the support aligns with the inner face of the base, the cupholder falls via gravity back to its vertical position, also aligned with the base. s

2.0.2 Rail, Rail Car, Clamps and Catch Blocks Description

2.02.2 Rail: The rail is in an L - shape that extends the length of the left armrest and bends to the front of the same arm rest. The rail has a clamp protruding from its side for connection to the wheelchair frame bars. The rail is also filleted top and bottom so that the wheels of the rail car can roll easily along the rail, and the rail car will move smoothly along the rail.

2.0.2.3 Rail Car: The rail car is the connection between the cup holder and the rail. On one side of the rail car, it connects to the base of the cupholder with 3 screws, triangularly positioned to provide maximum stability. On the opposite end of the car, 2 axles hold the wheels which slide on the rail. The center part of the car connects the wheel's axles with the base holder. The center part is extended to create room between the rail and the outer part of the handle so the cup is adjacent to the handle. The extension was done in triangular shapes to add stability. The lower triangle is cut in the center to allow placing a nut around the screw in the assembly process. The rail car also has magnets on either side to connect to the catch blocks so the cup can be stabilized in place.

2.0.2.4 Wheels: The wheels are angled inwards from both ends. One end is at a greater angle than the second to allow for free movement on the L part of the rail.

2.0.2.5 Clamps: The clamp is the complimentary piece to that attached to the rail and allows the rail to be attached to the wheelchair frame bars. This clamp is semicircle and is attached to the complimentary semicircle piece on the rail by 4 screws.

2.0.2.6 Catch Block: The catch block is a piece that is attached along the rail and holds the cup holder in place. There are two magnets in the side of the catch block, and two complimentary magnets in the rail car. The magnets allow the catch blocks to hold the railcar to them, keeping the cup holder in place. There is one catch block on the side rail section where the cup is most accessible, and another catch block at the front side of the rail where the cup holder will sit when not being used.

2.0.3 Materials

The main body of our design is made of AISI 4130 steel (normalized at 870° C) because of its high tensile strength, low cost, availability, and ease of use [4][5]. Specifically, AISI 4130 steel is comparable to aircraft-grade stainless steels, while being less expensive and more-easily machined [6]. The inner ring is also made of AISI 4130 Steel but annealed at 865 ° C. Annealed steel is more flexible and has a tighter bend radius than normalized steel [7]. As a result of the inner ring being most susceptible to dynamic use, the annealed steel was determined to be the best choice. The 10 mm small pin, bolt clamp and bearing are made of plain carbon steel (also known as low-carbon steel or mild steel [8].) As well as being the most widely available steel type, plain carbon steel is a good choice for fasteners because of its machinability and ability to meet the tight tolerances required for threading [8]. Plain carbon steel is also the cheapest of the carbon steel alloys [8]. The wheels are constructed out of natural rubber. Although the more expensive option in the past, natural rubber has reached a similar price point as the synthetic option within the past couple of years [9]. In comparison to two popular synthetic rubbers (neoprene and polyurethane,) natural rubber has a higher tensile strength and adheres to surfaces more effectively [10][11]. Natural rubber is often the material of choice for wheels/tires.

Table 2.0.3.1 - Material Properties of Natural Rubber

Property	Value	Units
Elastic Modulus	1.450377377	psi
Poisson's Ratio	0.45	N/A
Shear Modulus		psi
Mass Density	0.0346821905	lb/in^3
Tensile Strength	2900.754753	psi
Compressive Strength		psi
Yield Strength		psi
Thermal Expansion Coefficient		/°F
Thermal Conductivity		Btu/(in·sec·°F)
Specific Heat		Btu/(lb·°F)
Material Damping Ratio		N/A

Table 2.0.3.2 - Material Properties of Plain Carbon Steel

Property	Value	Units
Elastic Modulus	30457924.91	psi
Poisson's Ratio	0.28	N/A
Shear Modulus	11457981.28	psi
Mass Density	0.2817927981	lb/in^3
Tensile Strength	57989.8585	psi
Compressive Strength		psi
Yield Strength	31994.4547	psi
Thermal Expansion Coefficient	7.222222222e-06	/°F
Thermal Conductivity	0.000575114	Btu/(in·sec·°F)
Specific Heat	0.105092	Btu/(lb·°F)
Material Damping Ratio		N/A

Table 2.0.3.3 - Material Properties of AISI 4130 Steel (normalized at 870° C)

Property	Value	Units
Elastic Modulus	29732736.22	psi
Poisson's Ratio	0.285	N/A
Shear Modulus	11603019.01	psi
Mass Density	0.2835991622	lb/in^3
Tensile Strength	106022.5862	psi
Compressive Strength		psi
Yield Strength	66717.35933	psi
Thermal Expansion Coefficient		/°F
Thermal Conductivity	0.000571102	Btu/(in·sec·°F)
Specific Heat	0.113929	Btu/(lb·°F)
Material Damping Ratio		N/A

Table 2.0.3.4 - Material Properties of AISI 4130 Steel (annealed at 865° C)

Property	Value	Units
Elastic Modulus	29732736.22	psi
Poisson's Ratio	0.285	N/A
Shear Modulus	11603019.01	psi
Mass Density	0.2835991622	lb/in^3
Tensile Strength	81221.13309	psi
Compressive Strength		psi
Yield Strength	66717.35933	psi
Thermal Expansion Coefficient		/°F
Thermal Conductivity	0.000571102	Btu/(in·sec·°F)
Specific Heat	0.113929	Btu/(lb·°F)
Material Damping Ratio		N/A

2.0.4 Objective Comparison

Objective	Goal	Comparison
Accessibility	a. Should be able to move the cupholder to various locations adjacent to the left arm rest and within arm's reach at all times. b. Should be able to operate with only the left hand after installation.	Upon installation, the design allows the user to choose two custom positions adjacent to the Dual post Height Adjustable Flip Back Armrest. During use, the cup holder can easily be pushed with the left hand from one position to the next.
Expandability	c. Should be able to hold cup sizes ranging from diameters of 7 cm to 9 cm [Appendix B]	The design has a cupholder with an inner ring fitted with three flexible rubber flaps that allow for dynamic allotment of cups from minimum size 7 cm to maximum size 9 cm.
Stability	d. Should be able to hold the drink at angles of inclination/declination up to 30 degrees. [Appendix B]	The design has gyroscopic functionality allowing the cupholder to be level to the ground at angles of inclination/declination up to 30 degrees.
Collapsibility	e. Should be able to collapse to a protrusion that is 25% of the raised cupholder protrusion. [Appendix C]	The design collapses from a protrusion of 157.38 cm to 35 cm, yielding a collapsed protrusion of 22.2% of the raised protrusion.

2.1 Prototyping and Testing

2.0.1 Prototype

After all of the drawings were complete, the team pursued to build the parts using Solidworks software (.STL files) and assembled the pieces into assembly files (.SLDASM). Before moving on to processing the parts into G-code, final modifications were made to make sure that correct fitting and integration of the parts were complete. All of the pieces were sent into Makerspace for printing on Friday, November 20th after being processed with Tinkerine software, and the pieces were received on Tuesday, November 24th. (**Note:** The rail piece was too big to be printed in full. After consulting with the course instructor, it was decided to print part of rail in a way that still reflects all of the elements of its functionality). The team met on November 27th on campus to assemble the prototype, analyze and test its functionality.

Here are faults we found with the first prototype:

a. A design flaw was discovered that prevents the support to fully push into the base. The decision was made to immediately repair the design and resend it in for reprinting.
b. One of the flaps in the inner ring had broken off while cleaning the print-supports. Instead of reprinting this piece, the flap was reconnected to the inner-ring using epoxy putty, which proved very successful.
c. The sturdiness of the PLA the printer's at Makerspace use was overestimated, and, because of this, the bolts we printed were not sturdy enough to be screwed into tight threadings of the prototype. In the future, we will know to try and use real screws rather than printed ones.

Prototyping timeline:

November 8th - All 2D free-hand drawings completed.

November 13th - All 3d Solidworks parts completed.

November 20th - Assemblies completed, parts refined to integrate and fit, G-code created with Tinkerine, and all pieces sent into Makerspace for printing.

November 23rd - Pieces printed and picked up from campus.

November 25th - All external pieces for prototype purchased.

November 27th - Assembly of prototype, testing and assessing, "base" redesigned and sent in for reprinting.

2.0.2 Test Plan

Note: the test plans were made in reference to the prototype attached to the left of a user seated in an armchair

Objective	Test Plan	Results
Accessibility	1. Adjust the back catch block across the rail at various locations across the rail and fix points A and B. 2. Use the left-hand and move the cup holder from point A to point B at various locations adjacent to the rail.	1. The back catch block was fixable at points on the rail ranging across a total of length 18 cm adjacent to the user. 2. The user can use a single finger to push the cupholder across the rail from point A to point B (points were fixed such that length was maximized between points of attachment - 18 cm.)
Expandability	1. Place a cup of 7 cm diameter in the inner ring of the cup holder. 2. Place a cup of 9 cm diameter in the inner ring of the cup holder.	Although the cups fit within the area made available by the inner ring of the cupholder, the flaps located in the inner ring of the prototype are not flexible as indicated in the design details. Due to the rigid structure of the plastic prototype, the flexibility of the rubber flaps is not testable and requires testing.

Stability	1. Place a cup in the cupholder while the rail is at an angle of inclination of x degrees and use a level to check that the cup is level. 2. Place a cup in the cupholder while the rail is at an angle of declination of x degrees use a level to check that the cup is level.	The cupholder remains level at all angles of inclination. Note however, due to the limitation with the plastic rigid structure of the flaps, the cup to be tested had a diameter of Y. As a result, it is still required that the maximum cup size be tested to determine the correct range of the angle of inclination and declination where gyroscopic features will keep the cup level.
Collapsibility	1. Use your left hand to press down on the rings of the cupholder to engage the collapsing mechanism and ensure that the collapsed protrusion is 25% of the raised protrusion.	1. The rings collapse to 25% of the raised protrusion.

2.2 Cost Analysis

Calculated Parts	Quantity	Material Cost (USD/Part)	Manufacturing Cost (USD/Part)	Total Cost (USD / Assembly)
RAIL	1	45.17	32.67	77.84
OUTER CLAMP	2	0.28	8.74	18.04
CATCH BLOCK FRONT	1	0.46	8.70	9.16

CATCH BLOCK BACK	1	0.46	8.70	9.16
WHEEL	2	0.08	5.73	11.61
RAIL CAR	1	17.68	21.48	39.16
SUPPORT	1	0.45	11.31	11.76
10 MM SMALL PIN	4	0.00	2.80	11.22
BEARING	2	0.01	5.63	11.27
INNER RING	1	4.85	14.88	19.73
OUTER RING	1	10.26	16.67	26.93
BASE	1	13.75	13.25	27.00
ASSEMBLY	1	93.82	179.06	272.88

[Appendix G]

2.3 Implementation Requirements

Tetra society is made up of numerous volunteer engineers who are willing to invest time to construct and assemble the components of the design. Funding to attain the materials and corresponding supplies is allocated through campaigns conducted by Tetra Society in both Canada and the United States.

2.4 Manufacturing Process/Life Cycle

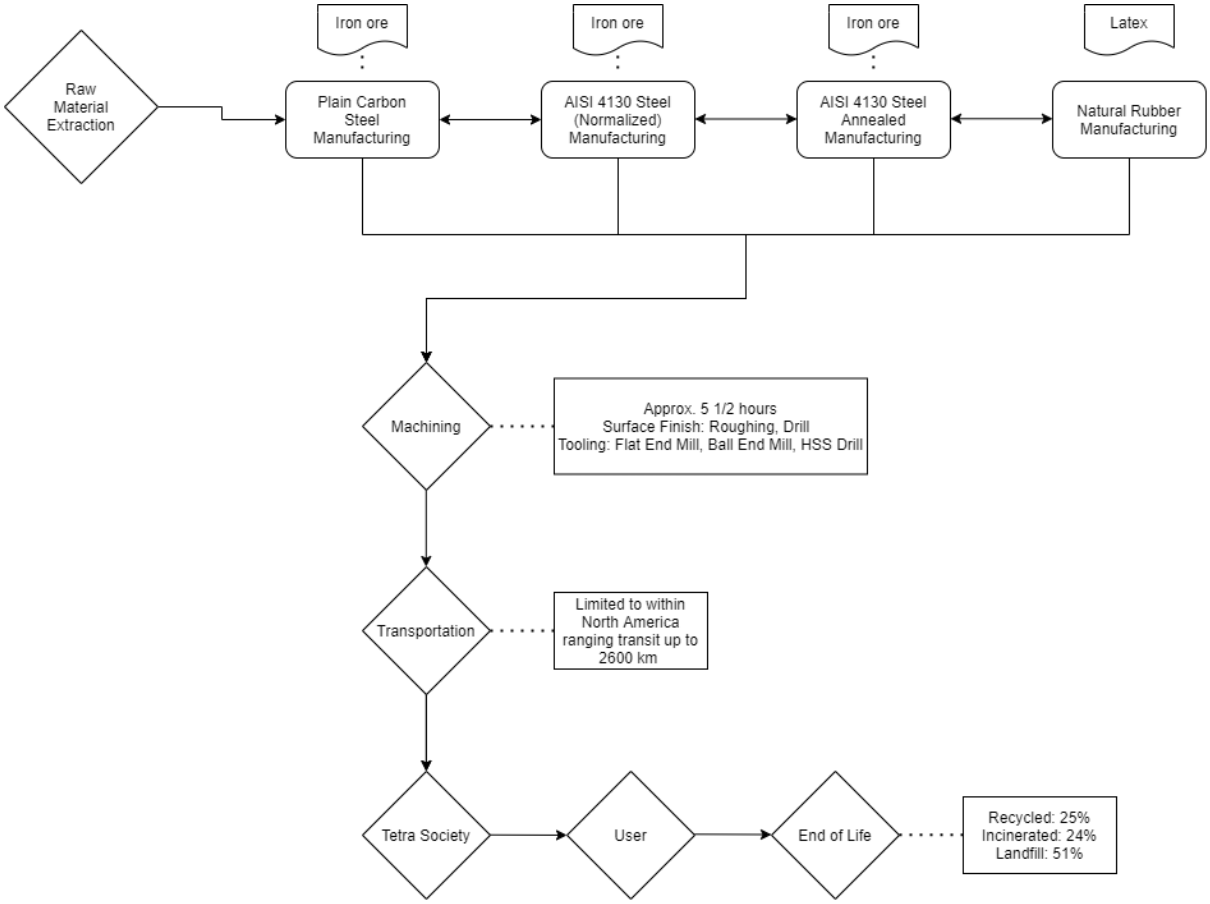


Figure 2.4.0.1 Life Cycle Assessment [Appendix F] [Appendix G]

Table 2.4.0.1 General Manufacturing Process of Materials

Material	Manufacturing Process
Steel (Plain Carbon and AISI 4130)	Manufacturing of steel is primarily a two step process [12]: 1. Liquid iron is burned in a furnace 2. Alloying metals are added and impurities are removed Plain carbon steel manufacturing involves using hot rolling or cold drawing to achieve the size of steel required [13]. Similar processes are used to obtain AISI 4130 Steel; however, the difference is that the AISI 4130 is alloyed steel. Alloyed steel involves combining alloying elements, such as manganese, silicon, nickel, titanium, copper, chromium and aluminium into the furnace in varying quantities to achieve the desired effect [14]. Annealing the alloyed steel involves allowing the material to cool at a controlled rate in a furnace. Normalizing the alloyed steel involves cooling at room temperature and exposing it to the air [15].

Rubber	Manufacturing of rubber involves initially harvesting rubber latex from a rubber tree with a process called tapping and further refining into rubber by coagulating the latex [16].

3.0 Bill of Materials

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	COST
1	R1	RAIL	1	77.84
2	R2	WHEEL	2	11.61
3	R3	RAIL CAR	1	39.16
4	R4	CATCH BLOCK FRONT	1	9.16
5	R5	OUTER CLAMP	2	18.04
6	R6	CATCH BLOCK BACK	1	9.16
7	C1	BASE	1	27.00
8	C2	10MM SMALL PIN	4	11.22

9	C3	SUPPORT	1	11.76
10	C4	INNER RING	1	19.73
11	C5	BEARING	2	11.27
12	C6	OUTER RING	1	26.93

[Appendix G]

4.0 Conclusion

The goal was to design a collapsible wheelchair holder for a left handed user of the Quickie S-646. Based on the client requirements, research of commercial cup holders and intricate engineering (from brainstorming to prototype testing), the team came up with the optimum solution of not only a conveniently placed collapsible cup holder, but also one fitted with gyroscopic functionality. The report ensures that the client is aware of the relevant standards/codes, implementation requirements, economics, and the life cycle assessment of the design. Upon approval of the client and associated parties, the design is ready for final revisions and is another step closer to production and to the user who needs it.

6.0 References

[1] Quickie S-636/S-646 SE Owner's Manual, pp.166
[2] British Columbia Building Code, 2018: http://free.bcpublications.ca/civix/document/id/public/bcbc2018/bcbc_2018dbp9s95.
[3] https://www.amazon.ca/Universal-Folding-Drink-Holder-Screws/dp/B08DNSYF7K/
[4]https://www.azom.com/article.aspx?ArticleID=6742
[5]http://elektroarsenal.net/wheeled-mobility-wheelchairs-and-personal-transportation.html#bookmark5693
[6]https://www.machinedesign.com/materials/article/21831967/comparing-stainless-steel-and-other-metals
[7]https://www.aedmotorsport.com/news/4130-normalized-vs-annealed-sheet
[8]https://www.uboltit.com/materials/carbon-steel.html
[9]https://www.bls.gov/opub/btn/volume-9/why-the-prices-of-natural-and-synthetic-rubber-do-not-always-bounce-together.htm

[10]https://sciencing.com/properties-natural-synthetic-rubber-7686133.html
[11]http://harknessindustries.com/rubber-polyurethane
[12][https://www.thermofisher.com/blog/metals/how-is-it-made-an-infographic-of-the-iron-and-steel-manufacturing-process]
[13][https://www.metalsupermarkets.com/what-is-mild-steel/]
[14]https://www.metalsupermarkets.com/alloy-steel-types/
[15]https://www.metalsupermarkets.com/what-is-normalizing/
[16][https://sciencing.com/manufacturing-process-rubber-5206099.html]

7.0 Appendices

Appendix A)

In our initial research we could not come up with a solution which met every requirement, so we decided to vote on the features that would fulfill certain requirements and base our final solution upon it. We categorized these features under 2 categories, the *fixture* which connects the cupholder to the wheelchair and the *cupholder* itself. The features we voted on were:

Table A1 - Votes on features which we would implement in our final solution

Fixture		Cup Holder	
1. double rail		5. Non-gyro	
2. Flex metal	IDDO Grant	6. gyro	Adin, Grant, Hamza Tyson
3. single rail	Adin IDDO Hamza Grant Tyson		

Now we explain each **feature mechanism and the **advantages** and **disadvantages****

1. Double Rail/Single Rail: The rail was chosen as the best solution for changing the position of the cupholder on an x-y plane. The main advantage of a rail system is the ability to move the cupholder to different positions to allow for accessibility and comfort for the user. As well, the L-shaped feature allows moving the cupholder in a way that the extra footprint created is not an issue while passing through tight doorways.

A double rail was found to be more stable vs a single rail system, however, the stability was not shown to be a major advantage as single raiWl systems in the market are shown to be

stable. The single rail was ultimately chosen as the double rail system was foreseen to be a more complicated design that might unnecessarily prolong the printing process as well as add complexity to the rail car and clamp designs and therefore hinder the design process.

2. Flex Metal: we wanted to use flex metal in the same way it holds up a microphone to hold the cupholder. Biggest advantage of flex metal is the accessibility it can provide (theoretically it can literally hold the cup holder at any position in a finite radius). However, the trade off is the space it takes up. You could fold it up every time it's not in use to conserve space but that would deform the metal faster. Not many resources available on the internet on its innate properties.

5. Non-gyro: defined as a cup holder without the gyro feature, no advantages, no disadvantages.

6. Gyro: To accommodate stability when the wheelchair is on incline, we wanted the cupholder to always be perpendicular to the horizon. The cup holder must be free to rotate about one plane and the spin axis of a gyroscope is exactly that, however adding a gyro feature would increase the radius of the cup holder.

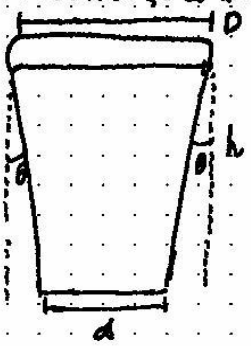
In the end, we picked the single rail for the fixture as it is sturdy enough to hold a cupholder and more and there are a wide range of resources on the web that we can reference in our design and implementation process. The flex metal while an innovative mention we didn't find much information on its properties such as the rigidity and how much weight it can support when extended and so in the interest of practicality, we discarded it. We also picked the gyro feature because the trade off of increased cupholder radius is negligible compared to the stability it adds to the system.

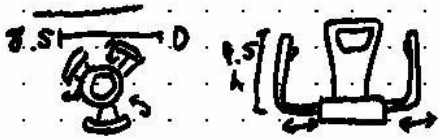
Appendix B)

Data on travel cups

cup	≈base D (cm)	≈top D (cm)	≈height (cm)	(g) weight	(oz) volume
Travel cup	9	9	27	400 g	20
	8	9	19.6	195	16
	8	9	15.4	100	15
	8	8	15.4	520	18
	7	8	13.9		14
	8	9	18.8	295	16
	9.4	9.4	18.3	408	24
Average	8	9	18.3	320	17.6

ex. from: contigo, Yeti, Ello, AIREE, Rink-Drink, Dewalt



model	expandable	D	notes
Nova	X conclusion: Too simple.	8.2 cm	- super simple - no modularity - no collapsibility - interesting connection mechanism
Uminsky	√ modular cup size doesn't decrease width by much	8.5 cm	- expansion mechanism: Top Side  - not sure how this would integrate with collapsibility.

cup holder research

model	expandable	D	notes
Bed Bath	X No	9 cm	- bottom with holes to allow for tight fit hold - tab flaps to grip cup - 10 cm height - plastic - interesting connection to chair idea (*) I did check at amazon
Wed Fair	√ in both ways	7.5 - 8.3 (cm)	- width (i) closed : 2.8 cm (ii) open : 9.2 cm  (i) (ii) - mechanisms (a) some sort of clip hold? (b) some sort of gear (*) more research / plastic gearing / plastic rack - all plastic - connection to chair - challenging

Conclusions:
- simple
- doable
- semi-effective

Conclusion:
- unclear mechanism
- very functional

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2 elements of expandibility:

(I) Whole piece itself expands and collaps to minimize space usage when idle. (affect cross-sectional area of chair)

(II) expandable in order to accomadate a range of cup sizes (more specifically - diameters).

Conclusions:

1. Most simple practical expandibility for width is the WedFeis [] → [] and also modularity [] both mechanisms need to be built. Options include:

- linear gears
- clops
- springs
- just friction.
- combination

2. Ranges of cups: max diameter: ≈ 9.5 cm
min diameter: ≈ 7 cm

3. Average height: 18.3 cm

$7 \leq \text{Diameter Range} \leq 9.5$

4. Average weight: 320 grams

Average liquid capacity: 17.6 ounces (≈ 500 g)

(*) Total average weight need to accomodate:

820 grams

(*) Max weight to accomodate: max weight + max liquid capacity

⇒ 500 g + 20 ounces (≈ 500 g) ≈ 1 kg of weight.

5. Could consider flaps - for stability.

6. Choice of expandibility mechanism depends on integration with connection to chair

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Appendix C)

Roads [edit]

In vehicular engineering, various land-based designs (automobiles, sport utility vehicles, trucks, trains, etc.) are rated for their ability to ascend terrain. Trains typically rate much lower than automobiles. The highest grade a vehicle can ascend while maintaining a particular speed is sometimes termed that vehicle's "gradeability" (or, less often, "grade ability"). The lateral slopes of a highway geometry are sometimes called fills or cuts where these techniques have been used to create them.

In the United States, maximum grade for Federally funded highways is specified in a design table based on terrain and design speeds,[3] with up to 6% generally allowed in mountainous areas and hilly urban areas with exceptions for up to 7% grades on mountainous roads with speed limits below 60 mph (95 km/h).

The steepest roads in the world are Baldwin Street in Dunedin, New Zealand, Ffordd Pen Llech in Harlech, Wales[4] and Canton Avenue in Pittsburgh, Pennsylvania.[5] The Guinness World Record once again lists Baldwin Street as the steepest street in the world, with a 34.8% grade (1 in 3.41) after a successful appeal[6] against the ruling that handed the title, briefly, to Ffordd Pen Llech. The Pittsburgh Department of Engineering and Construction recorded a grade of 37% (20°) for Canton Avenue.[7] The street has formed part of a bicycle race since 1983.[8]

The San Francisco Municipal Railway operates bus service among the city's hills. The steepest grade for bus operations is 23.1% by the *67-Bernal Heights* on Alabama Street between Ripley and Esmeralda Streets.[9]

10% slope warning sign, Netherlands | 7% descent warning sign, Finland | 25% ascent warning sign, Wales | 30% descent warning sign, over 1500 m. La Route des Crêtes, Cassis, France | A trolleybus climbing an 18% grade in Seattle | ascent of German Bundesstraße 10 | A car parked on Baldwin Street, Dunedin, New Zealand | Looking down Canton Avenue, Pittsburgh, Pennsylvania

Appendix D)

2pcs Universal Folding Cup Drink Holder for Car Truck Boat Van Home, Come with Screws and Tapes

Brand: Rojuna

★★★★★ 1 rating

Currently unavailable.

We don't know when or if this item will be back in stock.

- Convenient, corrosion-resistant onboard storage for your drinks (cups, cans, etc) holds cups or cans up to 75mm diameter
- Mounts on any flat vertical surface
- Easy to install - Includes stainless steel mounting fasteners and double-sided tape strips
- Folds flat to protrude only 23mm when closed, 100mm when open
- The plastic construction is totally waterproof and easy to clean

› See more product details

Report incorrect product information.

2pcs Adjustable Folding Cup Drink Holder with Screws and Tapes, Adjustable Automotive Cup Holders for Car TRUCK BOAT VAN. (Black)

Brand: WedFeir

★★★★½ 295 ratings | 4 answered questions

Was: ~~CDN$ 21.99~~

Price: CDN$ 18.99 & **FREE Shipping** on orders over CDN$ 35.00 . Details

You Save: CDN$ 3.00 (14%)

- WIDE APPLICATIONS: Easily adjust to hold almost any bottles can or mugs which Bottom diameter is less than 83mm.
- EASY TO INSTALL: Including 8 Stainless steel screws and double-sided tape strips.
- SMALL SIZES: Folds flat to protrude only 28mm when closed, 92mm when open.
- TOP QUALITY MATERIALS: The plastic construction is totally waterproof and easy to clean.
- EASY TO USE: The drink holder can be Mounted on any flat vertical surface.

AUTOUTLET 2 Packs Universal Adjustable Drinking Cup Holder Foldable for Car Truck Boat Van ...

Brand: AUTOUTLET

27 ratings

Was: ~~CDN$ 19.99~~

Price: CDN$ 17.95 & **FREE Shipping** on orders over CDN$ 35.00 . Details

You Save: CDN$ 2.04 (10%)

- High Quality, Stabilised ABS Plastic Construction.
- The Plastic Construction is Totally Waterproof and Easy to Clean.
- Adjustable Drink Holders Fold Flat to Protrude only 28mm When Closed, 100mm When Open.
- Adjustable Retainer Arms, Holds Cans, Cups, & Drink Bottles from 55mm to 75mm Diameter.
- Easy to Install - Includes Stainless Steel Mounting Fasteners and Double-sided Tape Strips.

› See more product details

JR Products 45623 Tan Adjustable Cup Holder

Brand: JR Products

322 ratings

Price: CDN$ 18.89 & **FREE Shipping** on orders over CDN$ 35.00 . Details

New (9) from CDN$ 18.89 & FREE Shipping on orders over CDN$ 35.00

Color Name: **Tan**

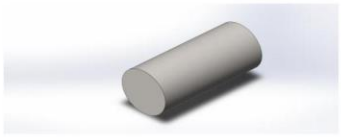
CDN$ 26.38 | **CDN$ 18.89** | CDN$ 21.60 | CDN$ 21.60

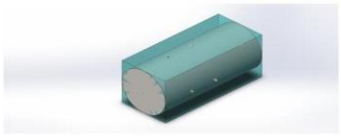
- Mounts easily to any flush surface
- Folds flat 4" x 4" when not in use
- Adjustable to hold up to 44 fl. oz.
- Made of sturdy ABS plastic
- Tan

› See more product details

Appendix E)

SOLIDWORKS Costing Report





Model Name:	10 MM SMALL PIN
Date and time of report:	2020-11-28 11:58:53 PM
Manufacturing Method:	Machining
Material:	Plain Carbon Steel
Stock weight:	0.00 lb
Stock Type	Block
Block Size:	0.18x0.18x0.39 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 2.81 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 2.81 USD Previous 2.81 USD

Cost Breakdown

Material:	0.00 USD	0%
Manufacturing:	2.80 USD	100%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:05:36

Setups:	00:05:35
Operations:	00:00:00

1

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Cost Report

Model Name:	10 MM SMALL PIN	Material:	Plain Carbon Steel	Material cost:	0.00 USD	Total cost /part:	2.81 USD
				Manufacturing cost:	2.80 USD	Total time /part:	00:05:36
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Total	**00:00:36**	**0.30**

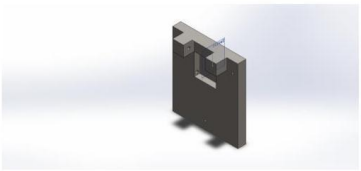
Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Total	**00:05:00**	**2.50**

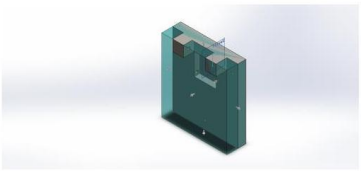
Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Volume 1	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 2	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 3	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 4	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Total		**0.00**	**00:00:00**	**0.00**		

Setup Operations

1. Setup Operation 1
    a. Volume 1
    b. Volume 3
    c. Volume 4
    d. Volume 2

SOLIDWORKS Costing Report





Model Name: BASE

Date and time of report:	2020-11-28 11:59:38 PM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	9.75 lb
Stock Type	Block
Block Size:	4.72x5.31x1.38 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 27.00 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 27.00 USD Previous 27.00 USD

Cost Breakdown

Material:	13.75 USD	51%
Manufacturing:	13.25 USD	49%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:26:30

Setups:	00:16:48
Operations:	00:09:42

1

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Cost Report

Model Name:	BASE	Material:	Plain Carbon Steel	Material cost:	13.75 USD	Total cost /part:	27.00 USD
				Manufacturing cost:	13.25 USD	Total time /part:	00:26:30
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Total	**00:01:47**	**0.90**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Total	**00:15:00**	**7.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Pocket 1	Roughing	0.06	00:00:01	0.01	Flat End Mill	N/A
Pocket 2	Roughing	0.98	00:00:23	0.20	Flat End Mill	N/A
Slot 1	Roughing	17.82	00:07:11	3.60	Flat End Mill	N/A
Slot 2	Roughing	0.78	00:00:18	0.16	Flat End Mill	N/A
Slot 2	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Total		**19.64**	**00:07:56**	**3.97**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.02	00:00:17	0.14	HSS Drill	N/A
Hole 2	Drill	0.02	00:00:17	0.14	HSS Drill	N/A

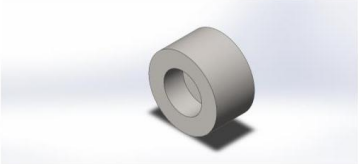
Hole 3	Drill	0.00	00:00:12	0.10	HSS Drill	N/A
Hole 4	Drill	0.00	00:00:12	0.10	HSS Drill	N/A
Hole 5	Drill	0.00	00:00:12	0.10	HSS Drill	N/A
Hole 6	Drill	0.02	00:00:17	0.14	HSS Drill	N/A
Hole 7	Drill	0.02	00:00:17	0.14	HSS Drill	N/A
Total		**0.09**	**00:01:46**	**0.88**		

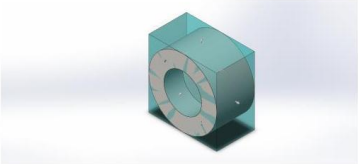
No Cost Features
Fillet 1
Fillet 2
Fillet 3
Fillet 4

Setup Operations

1. Setup Operation 1
    a. Pocket 1
    b. Pocket 2
    c. Slot 1
    d. Slot 2
    e. Hole 3
    f. Hole 4
    g. Hole 5
2. Setup Operation 2
    a. Hole 1
    b. Hole 6
3. Setup Operation 3
    a. Hole 7
    b. Hole 2

SOLIDWORKS Costing Report





Model Name: BEARING

Date and time of report:	2020-11-29 12:01:09 AM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	0.01 lb
Stock Type	Block
Block Size:	0.35x0.35x0.20 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 5.64 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 5.64 USD Previous 5.64 USD

Cost Breakdown

Material:	0.01 USD	0%
Manufacturing:	5.63 USD	100%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:11:15

Setups:	00:11:11
Operations:	00:00:03

1

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Cost Report

Model Name:	BEARING	Material:	Plain Carbon Steel	Material cost:	0.01 USD	Total cost /part:	5.64 USD
				Manufacturing cost:	5.63 USD	Total time /part:	00:11:15
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Total	**00:01:11**	**0.60**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Total	**00:10:00**	**5.00**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Volume 1	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 2	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 3	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 4	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Total		**0.01**	**00:00:00**	**0.00**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.00	00:00:02	0.02	HSS Drill	N/A
Total		**0.00**	**00:00:02**	**0.02**		

Setup Operations

1. Setup Operation 1
    a. Hole 1
2. Setup Operation 2
    a. Volume 4

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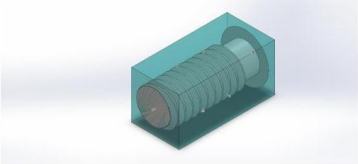
b. Volume 3
c. Volume 1
d. Volume 2

3

SOLIDWORKS Costing Report



Model Name: BOLT CLAMP

Date and time of report:	2020-11-29 12:03:41 AM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	0.02 lb
Stock Type	Block
Block Size:	0.31x0.31x0.63 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 2.83 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	100% Current 2.83 USD

Cost Breakdown

Material:	0.02 USD	1%
Manufacturing:	2.81 USD	99%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:05:36

Setups:	00:05:35
Operations:	00:00:00

1

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Cost Report

Model Name:	BOLT CLAMP	Material:	Plain Carbon Steel	Material cost:	0.02 USD	Total cost /part:	2.83 USD
				Manufacturing cost:	2.81 USD	Total time /part:	00:05:36
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Total	**00:00:36**	**0.30**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Total	**00:05:00**	**2.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Volume 1	Roughing	0.04	00:00:00	0.01	Flat End Mill	N/A
Total		**0.04**	**00:00:00**	**0.01**		

Setup Operations

1. Setup Operation 1
   a. Volume 1

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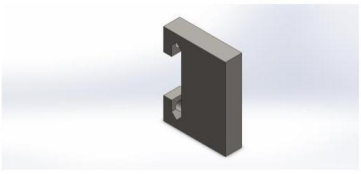
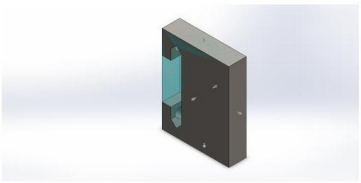
SOLIDWORKS Costing Report





Model Name:	CATCH BLOCK BACK
Date and time of report:	2020-11-29 12:04:29 AM
Manufacturing Method:	Machining
Material:	Plain Carbon Steel
Stock weight:	0.33 lb
Stock Type	Block
Block Size:	1.50x1.97x0.39 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 9.16 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 9.16 USD Previous 9.16 USD

Cost Breakdown

Material:	0.46 USD	5%
Manufacturing:	8.70 USD	95%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:17:24

Setups:	00:16:48
Operations:	00:00:36

1

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Cost Report

Model Name:	CATCH BLOCK BACK	Material:	Plain Carbon Steel	Material cost:	0.46 USD	Total cost /part:	9.16 USD
				Manufacturing cost:	8.70 USD	Total time /part:	00:17:24
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Total	**00:01:47**	**0.90**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Total	**00:15:00**	**7.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Slot 1	Roughing	0.21	00:00:05	0.04	Flat End Mill	N/A
Total		**0.21**	**00:00:05**	**0.04**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Hole 2	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Hole 3	Drill	0.02	00:00:07	0.07	HSS Drill	N/A
Hole 4	Drill	0.02	00:00:07	0.07	HSS Drill	N/A
Total		**0.06**	**00:00:31**	**0.26**		

Setup Operations

1. Setup Operation 1
    a. Slot 1

2. Setup Operation 2
    a. Hole 1
    b. Hole 2
3. Setup Operation 3
    a. Hole 3
    b. Hole 4

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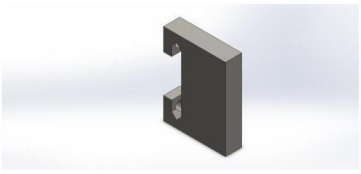
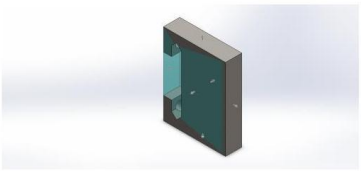
SOLIDWORKS Costing Report





Model Name:	CATCH BLOCK FRONT
Date and time of report:	2020-11-29 12:05:16 AM
Manufacturing Method:	Machining
Material:	Plain Carbon Steel
Stock weight:	0.33 lb
Stock Type	Block
Block Size:	1.50x1.97x0.39 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 9.16 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 9.16 USD Previous 9.16 USD

Cost Breakdown

Material:	0.46 USD	5%
Manufacturing:	8.70 USD	95%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:17:24

Setups:	00:16:48
Operations:	00:00:36

1

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Cost Report

Model Name:	CATCH BLOCK FRONT	Material:	Plain Carbon Steel	Material cost:	0.46 USD	Total cost /part:	9.16 USD
				Manufacturing cost:	8.70 USD	Total time /part:	00:17:24
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Total	**00:01:47**	**0.90**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Total	**00:15:00**	**7.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Slot 1	Roughing	0.21	00:00:05	0.04	Flat End Mill	N/A
Total		**0.21**	**00:00:05**	**0.04**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Hole 2	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Hole 3	Drill	0.02	00:00:07	0.07	HSS Drill	N/A
Hole 4	Drill	0.02	00:00:07	0.07	HSS Drill	N/A
Total		**0.06**	**00:00:31**	**0.26**		

Setup Operations

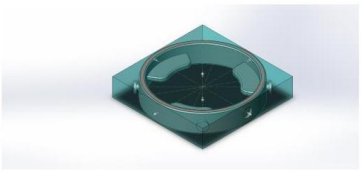
1. Setup Operation 1
    a. Slot 1

2

2. Setup Operation 2
    a. Hole 2
    b. Hole 1
3. Setup Operation 3
    a. Hole 3
    b. Hole 4

3

SOLIDWORKS Costing Report



Model Name: INNER RING

Date and time of report:	2020-11-29 12:06:40 AM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	3.44 lb
Stock Type	Block
Block Size:	3.94x0.79x3.94 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 19.73 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 19.73 USD Previous 19.73 USD

Cost Breakdown

Material:	4.85 USD	25%
Manufacturing:	14.88 USD	75%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:29:46

Setups:	00:28:00
Operations:	00:01:46

1

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Cost Report

Model Name:	INNER RING	Material:	Plain Carbon Steel	Material cost:	4.85 USD	Total cost /part:	19.73 USD
				Manufacturing cost:	14.88 USD	Total time /part:	00:29:46
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Setup Operation 4	00:00:36	0.30
Setup Operation 5	00:00:36	0.30
Total	**00:03:00**	**1.50**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Setup Operation 4	00:05:00	2.50
Setup Operation 5	00:05:00	2.50
Total	**00:25:00**	**12.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Slot 1	Roughing	0.25	00:00:05	0.05	Flat End Mill	N/A
Slot 1	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Slot 2	Roughing	0.25	00:00:05	0.05	Flat End Mill	N/A
Slot 2	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Slot 3	Roughing	0.25	00:00:05	0.05	Flat End Mill	N/A
Slot 3	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A

Slot 4	Roughing	0.25	00:00:05	0.05	Flat End Mill	N/A
Slot 4	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Slot 5	Roughing	0.25	00:00:05	0.05	Flat End Mill	N/A
Slot 5	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Slot 6	Roughing	0.25	00:00:05	0.05	Flat End Mill	N/A
Slot 6	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Volume 1	Roughing	2.57	00:01:02	0.52	Flat End Mill	N/A
Total		**4.04**	**00:01:38**	**0.82**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.01	00:00:03	0.03	HSS Drill	N/A
Hole 2	Drill	0.01	00:00:03	0.03	HSS Drill	N/A
Total		**0.02**	**00:00:07**	**0.07**		

No Cost Features
Pocket 1
Fillet 1
Fillet 2
Fillet 3
Fillet 4
Fillet 5
Fillet 6
Fillet 7
Fillet 8

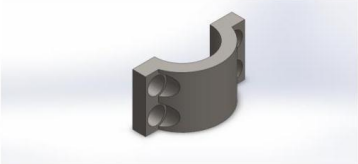
Setup Operations

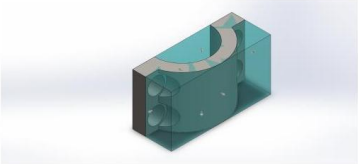
1. Setup Operation 1
    a. Slot 2
    b. Slot 3
    c. Slot 1
2. Setup Operation 2

3

    a. Slot 4
    b. Slot 6
    c. Slot 5
3. Setup Operation 3
    a. Hole 1
4. Setup Operation 4
    a. Hole 2
5. Setup Operation 5
    a. Volume 1

SOLIDWORKS Costing Report





Model Name: OUTER CLAMP

Date and time of report:	2020-11-29 12:10:16 AM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	0.20 lb
Stock Type	Block
Block Size:	0.59x0.79x1.51 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 9.02 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 9.02 USD Previous 9.02 USD

Cost Breakdown

Material:	0.28 USD	3%
Manufacturing:	8.74 USD	97%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:17:28

Setups:	00:16:48
Operations:	00:00:40

1

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Cost Report

Model Name:	OUTER CLAMP	Material:	Plain Carbon Steel	Material cost:	0.28 USD	Total cost /part:	9.02 USD
				Manufacturing cost:	8.74 USD	Total time /part:	00:17:28
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Total	**00:01:47**	**0.90**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Total	**00:15:00**	**7.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Slot 1	Roughing	0.22	00:00:05	0.04	Flat End Mill	N/A
Volume 1	Roughing	0.11	00:00:02	0.02	Flat End Mill	N/A
Volume 2	Roughing	0.11	00:00:02	0.02	Flat End Mill	N/A
Total		**0.45**	**00:00:10**	**0.09**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Hole 2	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Hole 3	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Hole 4	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Total		**0.04**	**00:00:29**	**0.25**		

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Setup Operations

1. Setup Operation 1
    a. Slot 1
2. Setup Operation 2
    a. Hole 1
    b. Hole 4
    c. Hole 3
    d. Hole 2
3. Setup Operation 3
    a. Volume 2
    b. Volume 1

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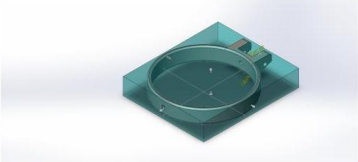
SOLIDWORKS Costing Report



Model Name: OUTER RING

Date and time of report:	2020-11-29 12:09:26 AM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	7.28 lb
Stock Type	Block
Block Size:	4.72x0.98x5.56 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 26.93 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 26.93 USD Previous 26.93 USD

Cost Breakdown

Material:	10.26 USD	38%
Manufacturing:	16.67 USD	62%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:33:19

Setups:	00:28:00
Operations:	00:05:19

1

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Cost Report

Model Name:	OUTER RING	Material:	Plain Carbon Steel	Material cost:	10.26 USD	Total cost /part:	26.93 USD
				Manufacturing cost:	16.67 USD	Total time /part:	00:33:19
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Setup Operation 4	00:00:36	0.30
Setup Operation 5	00:00:36	0.30
Total	**00:03:00**	**1.50**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Setup Operation 4	00:05:00	2.50
Setup Operation 5	00:05:00	2.50
Total	**00:25:00**	**12.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Slot 1	Roughing	0.50	00:00:12	0.10	Flat End Mill	N/A
Volume 1	Roughing	11.09	00:04:28	2.24	Flat End Mill	N/A
Total		**11.59**	**00:04:41**	**2.34**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.01	00:00:11	0.09	HSS Drill	N/A
Hole 2	Drill	0.01	00:00:11	0.09	HSS Drill	N/A

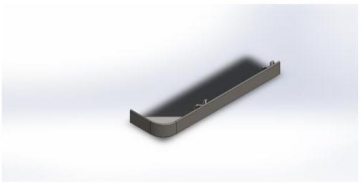
Hole 3	Drill	0.02	00:00:06	0.05	HSS Drill	N/A
	C'Bore	0.01	00:00:03	0.03	HSS Drill	N/A
Hole 4	Drill	0.01	00:00:07	0.06	HSS Drill	N/A
Total		**0.06**	**00:00:38**	**0.32**		

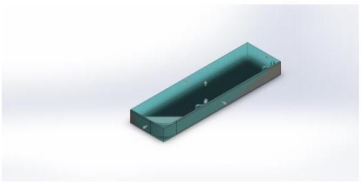
No Cost Features
Slot 2
Slot 3
Hole 5
Fillet 1
Fillet 2
Fillet 3

Setup Operations

1. Setup Operation 1
    a. Slot 1
2. Setup Operation 2
    a. Hole 1
    b. Hole 2
3. Setup Operation 3
    a. Hole 3
    b. Hole 4
4. Setup Operation 4
    a. Hole 3
5. Setup Operation 5
    a. Volume 1

SOLIDWORKS Costing Report





Model Name: RAIL

Date and time of report:	2020-11-29 12:12:46 AM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	32.04 lb
Stock Type	Block
Block Size:	4.53x1.57x15.94 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 77.84 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 77.84 USD Previous 77.84 USD

Cost Breakdown

Material:	45.17 USD	58%
Manufacturing:	32.67 USD	42%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 01:05:20

Setups:	00:22:23
Operations:	00:42:56

1

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Cost Report

Model Name:	RAIL	Material:	Plain Carbon Steel	Material cost:	45.17 USD	Total cost /part:	77.84 USD
				Manufacturing cost:	32.67 USD	Total time /part:	01:05:20
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Setup Operation 4	00:00:36	0.30
Total	**00:02:23**	**1.20**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Setup Operation 4	00:05:00	2.50
Total	**00:20:00**	**10.00**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Pocket 1	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Pocket 2	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Pocket 3	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Pocket 4	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Pocket 5	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Pocket 6	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Pocket 7	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Pocket 8	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A

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Slot 1	Roughing	0.22	00:00:05	0.04	Flat End Mill	N/A
Slot 2	Roughing	0.22	00:00:05	0.04	Flat End Mill	N/A
Slot 3	Roughing	4.06	00:01:38	0.82	Flat End Mill	N/A
Slot 6	Roughing	2.03	00:00:49	0.41	Flat End Mill	N/A
Slot 9	Roughing	7.99	00:03:13	1.61	Flat End Mill	N/A
Volume 1	Roughing	1.25	00:00:30	0.25	Flat End Mill	N/A
Volume 2	Roughing	90.46	00:36:32	18.27	Flat End Mill	N/A
Total		**106.30**	**00:42:56**	**21.47**		

No Cost Features
Slot 4
Slot 5
Slot 7
Slot 8
Slot 10
Slot 11
Slot 12
Slot 13
Fillet 1
Fillet 2
Fillet 3

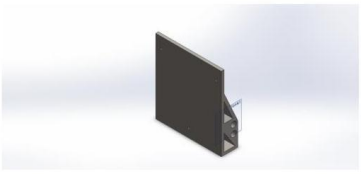
Setup Operations

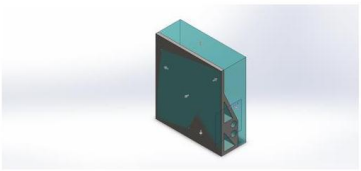
1. Setup Operation 1
    a. Pocket 7
    b. Pocket 2
    c. Pocket 5
    d. Pocket 1
    e. Pocket 3
    f. Pocket 8
    g. Pocket 6
    h. Pocket 4
2. Setup Operation 2

3

   a. Slot 3
   b. Slot 1
   c. Slot 2
   d. Slot 9
3. Setup Operation 3
   a. Slot 6
4. Setup Operation 4
   a. Volume 2
   b. Volume 1

SOLIDWORKS Costing Report





Model Name: RAIL CAR

Date and time of report:	2020-11-29 12:11:30 AM

Manufacturing Method: Machining

Material:	Plain Carbon Steel
Stock weight:	12.54 lb
Stock Type	Block
Block Size:	4.72x5.31x1.77 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 39.16 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 39.16 USD Previous 39.16 USD

Cost Breakdown

Material:	17.68 USD	45%
Manufacturing:	21.48 USD	55%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:42:58

Setups:	00:28:00
Operations:	00:14:58

1

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Cost Report

Model Name:	RAIL CAR	Material:	Plain Carbon Steel	Material cost:	17.68 USD	Total cost /part:	39.16 USD
				Manufacturing cost:	21.48 USD	Total time /part:	00:42:58
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Setup Operation 4	00:00:36	0.30
Setup Operation 5	00:00:36	0.30
Total	**00:03:00**	**1.50**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Setup Operation 4	00:05:00	2.50
Setup Operation 5	00:05:00	2.50
Total	**00:25:00**	**12.50**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Slot 1	Roughing	7.96	00:03:13	1.61	Flat End Mill	N/A
Pocket 1	Roughing	2.06	00:00:49	0.42	Flat End Mill	N/A
Pocket 2	Roughing	2.20	00:00:53	0.44	Flat End Mill	N/A
Slot 2	Roughing	2.97	00:01:11	0.60	Flat End Mill	N/A
Volume 1	Roughing	0.58	00:00:14	0.12	Flat End Mill	N/A
Volume 2	Roughing	1.41	00:00:34	0.29	Flat End Mill	N/A

Volume 3	Roughing	0.58	00:00:13	0.12	Flat End Mill	N/A
Volume 4	Roughing	1.41	00:00:34	0.29	Flat End Mill	N/A
Volume 5	Roughing	14.75	00:05:57	2.98	Flat End Mill	N/A
Total		**33.91**	**00:13:41**	**6.85**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.05	00:00:15	0.13	HSS Drill	N/A
Hole 2	Drill	0.05	00:00:15	0.13	HSS Drill	N/A
Hole 3	Drill	0.05	00:00:15	0.13	HSS Drill	N/A
Hole 4	Drill	0.05	00:00:15	0.13	HSS Drill	N/A
Hole 5	Drill	0.00	00:00:04	0.03	HSS Drill	N/A
Hole 6	Drill	0.00	00:00:04	0.03	HSS Drill	N/A
Hole 7	Drill	0.00	00:00:04	0.03	HSS Drill	N/A
Total		**0.20**	**00:01:16**	**0.63**		

Setup Operations

1. Setup Operation 1
    a. Slot 1
    b. Hole 7
    c. Slot 2
    d. Hole 6
    e. Hole 5
2. Setup Operation 2
    a. Pocket 1
    b. Pocket 2
3. Setup Operation 3
    a. Hole 3
    b. Hole 1
4. Setup Operation 4
    a. Hole 2
    b. Hole 4
5. Setup Operation 5
    a. Volume 1
    b. Volume 2
    c. Volume 3
    d. Volume 5
    e. Volume 4

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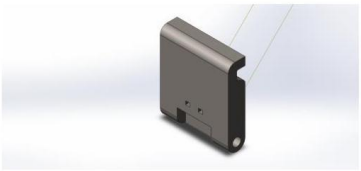
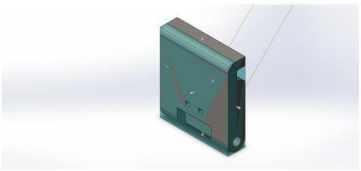
SOLIDWORKS Costing Report





Model Name:	SUPPORT
Date and time of report:	2020-11-29 12:13:31 AM
Manufacturing Method:	Machining
Material:	Plain Carbon Steel
Stock weight:	0.32 lb
Stock Type	Block
Block Size:	1.57x1.81x0.39 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce

Total number of parts:	100
Lot size:	100

Estimated cost per part: 11.76 USD

Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 11.76 USD Previous 11.76 USD

Cost Breakdown

Material:	0.45 USD	4%
Manufacturing:	11.31 USD	96%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part: 00:22:37

Setups:	00:22:23
Operations:	00:00:13

1

SOLIDWORKS

Cost Report

Model Name:	SUPPORT	Material:	Plain Carbon Steel	Material cost:	0.45 USD	Total cost /part:	11.76 USD
				Manufacturing cost:	11.31 USD	Total time /part:	00:22:37
				Markup:	0.00 USD		

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Setup Operation 3	00:00:36	0.30
Setup Operation 4	00:00:36	0.30
Total	**00:02:23**	**1.20**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Setup Operation 3	00:05:00	2.50
Setup Operation 4	00:05:00	2.50
Total	**00:20:00**	**10.00**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Pocket 1	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Pocket 1	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Slot 1	Roughing	0.06	00:00:01	0.01	Flat End Mill	N/A
Pocket 2	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Pocket 2	Roughing	0.00	00:00:00	0.00	Ball End Mill	N/A
Volume 1	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 2	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 3	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A

2

Volume 4	Roughing	0.00	00:00:00	0.00	Flat End Mill	N/A
Volume 5	Roughing	0.01	00:00:00	0.00	Flat End Mill	N/A
Total		**0.09**	**00:00:02**	**0.02**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 3	Drill	0.01	00:00:05	0.05	HSS Drill	N/A
Hole 4	Drill	0.01	00:00:05	0.05	HSS Drill	N/A
Total		**0.01**	**00:00:11**	**0.10**		

No Cost Features
Slot 2
Hole 1
Hole 2
Fillet 1
Fillet 2
Fillet 3
Fillet 4
Fillet 5

Setup Operations

1. Setup Operation 1
    a. Slot 1
    b. Pocket 2
    c. Pocket 1
2. Setup Operation 2
    a. Hole 3
3. Setup Operation 3
    a. Hole 4
4. Setup Operation 4
    a. Volume 1
    b. Volume 2
    c. Volume 3
    d. Volume 4
    e. Volume 5

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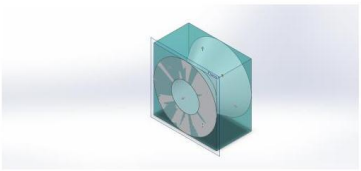
SOLIDWORKS Costing Report



Model Name:	WHEEL
Date and time of report:	2020-11-29 12:15:01 AM

Manufacturing Method:	Machining
Material:	Plain Carbon Steel
Stock weight:	0.06 lb
Stock Type	Block
Block Size:	0.71x0.71x0.39 in
Material cost/weight:	1.41 USD/lb
Shop Rate:	N/A

Quantity to Produce	
Total number of parts:	100
Lot size:	100

Estimated cost per part:	5.81 USD
Costing template used:	machiningtemplate_default(englishstandard).sldctm
Costing mode used:	Manufacturing Process Recognition
Comparison:	0% Current 5.81 USD Previous 5.81 USD

Cost Breakdown		
Material:	0.08 USD	1%
Manufacturing:	5.73 USD	99%
Markup:	0.00 USD	0%
Mold:	0.00 USD	0%

Estimated time per part:	00:11:27
Setups:	00:11:11
Operations:	00:00:15

1

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Cost Report

Model Name:	WHEEL	Material:	Plain Carbon Steel	Material cost: 0.08 USD Manufacturing cost: 5.73 USD Markup: 0.00 USD	Total cost /part: 5.81 USD Total time /part: 00:11:27

Manufacturing Cost Breakdown

Operation Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:00:36	0.30
Setup Operation 2	00:00:36	0.30
Total	**00:01:11**	**0.60**

Load and Unload Setups	Time (hh:mm:ss)	Cost (USD / Part)
Setup Operation 1	00:05:00	2.50
Setup Operation 2	00:05:00	2.50
Total	**00:10:00**	**5.00**

Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Volume 1	Roughing	0.10	00:00:02	0.02	Flat End Mill	N/A
Total		**0.10**	**00:00:02**	**0.02**		

Hole Operation	Surface Finish	Volume Removed (in^3)	Time (hh:mm:ss)	Cost (USD / Part)	Tooling	Cost-per-Volume (USD/in^3)
Hole 1	Drill	0.03	00:00:12	0.11	HSS Drill	N/A
Total		**0.03**	**00:00:12**	**0.11**		

Setup Operations

1. Setup Operation 1
    a. Hole 1
2. Setup Operation 2
    a. Volume 1

Appendix F)

SOLIDWORKS Costing Report

Assembly Name:	RAIL + RAIL CAR + CUPHOLDER
Date and time of report:	2020-11-29 12:15:41 AM
Total weight:	11.79 lb
Total stock weight:	66.54 lb

Quantity to Produce

Total number of assemblies:	1
Lot size:	1

Estimated cost per assembly: 282.90 USD

Costing main template:	multibodytemplate_default(englishstandard).sldctc
Comparison:	0% Current 282.90 USD Previous 282.90 USD

Cost Breakdown

Calculated Parts:	272.88 USD	96%
Purchased Parts:	0.00 USD	0%
Toolbox Parts:	0.00 USD	0%
Operations:	10.02 USD	4%
Markup:	0.00 USD	0%

1

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Component Cost Impact

Top Ten Components Contributing Most to Assembly Cost

Component	Configuration	Material Cost (USD/Assembly)	Manufacturing Cost (USD/Assembly)	Total Cost (USD/Assembly)
RAIL	Default	45.17	32.67	77.84
RAIL CAR	Default	17.68	21.48	39.16
BASE	Default	13.75	13.25	27.00
OUTER RING	Default	10.26	16.67	26.93
INNER RING	Default	4.85	14.88	19.73
SUPPORT	Default	0.45	11.31	11.76
CATCH BLOCK FRONT	Default	0.46	8.70	9.16
CATCH BLOCK BACK	Default	0.46	8.70	9.16
OUTER CLAMP	Default	0.28	8.74	9.02
WHEEL	Default	0.08	5.73	5.81
Total		93.43	142.14	235.57

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Cost Breakdown for Each Part

Calculated Parts	Method	Quantity	Part Cost (USD/Assembly)	Total Cost (USD / Assembly)	Costing Template
RAIL [Default]	Machining	1	77.84	77.84	machiningtemplate_default(english standard).sldctm
OUTER CLAMP [Default]	Machining	2	9.02	18.04	machiningtemplate_default(english standard).sldctm
CATCH BLOCK FRONT [Default]	Machining	1	9.16	9.16	machiningtemplate_default(english standard).sldctm
CATCH BLOCK BACK [Default]	Machining	1	9.16	9.16	machiningtemplate_default(english standard).sldctm
WHEEL [Default]	Machining	2	5.81	11.61	machiningtemplate_default(english standard).sldctm
RAIL CAR [Default]	Machining	1	39.16	39.16	machiningtemplate_default(english standard).sldctm
SUPPORT [Default]	Machining	1	11.76	11.76	machiningtemplate_default(english standard).sldctm
10 MM SMALL PIN [Default]	Machining	4	2.81	11.22	machiningtemplate_default(english standard).sldctm
BEARING [Default]	Machining	2	5.64	11.27	machiningtemplate_default(english standard).sldctm
INNER RING [Default]	Machining	1	19.73	19.73	machiningtemplate_default(english standard).sldctm
OUTER RING [Default]	Machining	1	26.93	26.93	machiningtemplate_default(english standard).sldctm
BASE [Default]	Machining	1	27.00	27.00	machiningtemplate_default(english standard).sldctm
Total			244.01	272.88	

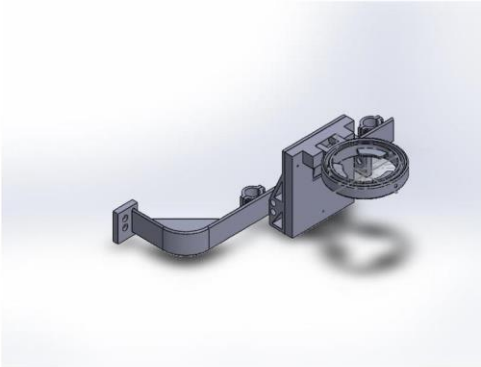
SOLIDWORKS

Appendix G)

[company logo here]

SOLIDWORKS
Sustainability Report

[company name here] [city, state here] [company url here]



Model Name: RAIL + RAIL CAR + CUPHOLDER

Weight: 5368.66 g

Built to last: 10 year

Duration of use: 1.0 year

Manufacturing Region
The choice of manufacturing region determines the energy sources and technologies used in the modeled material creation and manufacturing steps of the product's life cycle.

Use Region
The use region is used to determine the energy sources consumed during the product's use phase (if applicable) and the destination for the product at its end-of-life. Together with the manufacturing region, the use region is also used to estimate the environmental impacts associated with transporting the product from its manufacturing location to its use location.

Tetra Society of North America

Sustainability Report

Model Name:	RAIL + RAIL CAR + CUPHOLDER	Weight:	5368.66 g
		Built to last:	10 year
		Duration of use:	1.0 year

Assembly Process

Region:	North America
Energy type:	None
Energy amount:	0.00 kWh
Built to last:	10 year

Use

Region:	North America
Energy type:	None
Energy amount:	0.00 kWh
Duration of use:	1.0 year

Transportation

Truck distance:	2600 km
Train distance:	0.00 km
Ship distance:	0.00 km
Airplane Distance:	0.00 km

End of Life

Recycled:	25 %
Incinerated:	24 %
Landfill:	51 %

Comments

Click here for alternative units such as 'Miles Driven in a Car'

SOLIDWORKS

Tetra Society of North America

Sustainability Report

Model Name:	RAIL + RAIL CAR + CUPHOLDER	Weight:	5368.66 g
		Built to last:	10 year
		Duration of use:	1.0 year

Environmental Impact (calculated using CML impact assessment methodology)

Carbon Footprint

Material:	11 kg CO_2e
Manufacturing:	3900 kg CO_2e
Use:	0.00 kg CO_2e
Transportation:	1.0 kg CO_2e
End of Life:	3.6 kg CO_2e

3900 kg CO_2e

Total Energy Consumed

Material:	140 MJ
Manufacturing:	3.9E+4 MJ
Use:	0.00 MJ
Transportation:	15 MJ
End of Life:	2.7 MJ

3.9E+4 MJ

Air Acidification

Material:	0.035 kg SO_2e
Manufacturing:	55 kg SO_2e
Use:	0.00 kg SO_2e
Transportation:	4.6E-3 kg SO_2e
End of Life:	2.1E-3 kg SO_2e

55 kg SO_2e

Water Eutrophication

Material:	0.010 kg PO_4e
Manufacturing:	2.1 kg PO_4e
Use:	0.00 kg PO_4e
Transportation:	1.0E-3 kg PO_4e
End of Life:	3.6E-3 kg PO_4e

2.1 kg PO_4e

Material Financial Impact 2.80 USD

Comments

Click here for alternative units such as 'Miles Driven in a Car'

SOLIDWORKS

Tetra Society of North America

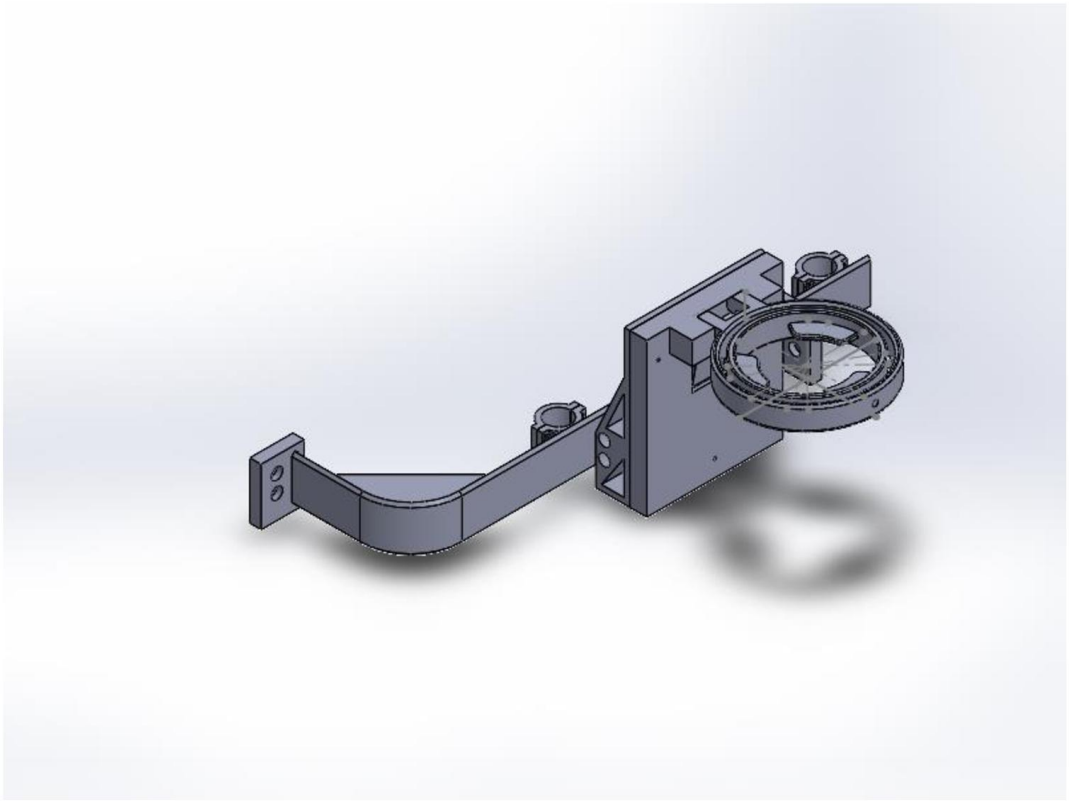
Sustainability Report

Model Name:	RAIL + RAIL CAR + CUPHOLDER	Weight:	5368.66 g
		Built to last:	10 year
		Duration of use:	1.0 year

Component Environmental Impact

Top Ten Components Contributing Most to the Four Areas of Environmental Impact

Component	Carbon	Water	Air	Energy
BASE	1400	0.747	19	1.4E+4
RAIL CAR	1100	0.576	15	1.1E+4
RAIL	720	0.391	10	7100
OUTER RING	240	0.130	3.3	2400
INNER RING	210	0.114	2.9	2100
SUPPORT	88	0.048	1.2	880
CATCH BLOCK BACK	83	0.045	1.2	830
CATCH BLOCK FRONT	83	0.045	1.2	830
OUTER CLAMP	20	0.011	0.279	200
BEARING	1.5	8.3E-4	0.021	15



Comments

Click here for alternative units such as 'Miles Driven in a Car'


RAW MATERIAL EXTRACTION
MATERIAL PROCESSING
PART MANUFACTURING
ASSEMBLY
PRODUCT USE
END OF LIFE
SUSTAINABLE DESIGN
SOLIDWORKS

Glossary

Air Acidification - Sulfur dioxide, nitrous oxides other acidic emissions to air cause an increase in the acidity of rainwater, which in turn acidifies lakes and soil. These acids can make the land and water toxic for plants and aquatic life. Acid rain can also slowly dissolve manmade building materials such as concrete. This impact is typically measured in units of either kg **sulfur dioxide equivalent (SO_2), or moles H+ equivalent**.

Carbon Footprint - Carbon-dioxide and other gasses which result from the burning of fossil fuels accumulate in the atmosphere which in turn increases the earth's average temperature. Carbon footprint acts as a proxy for the larger impact factor referred to as Global Warming Potential (GWP). Global warming is blamed for problems like loss of glaciers, extinction of species, and more extreme weather, among others.

Total Energy Consumed - A measure of the non-renewable energy sources associated with the part's lifecycle in units of megajoules (**MJ**). This impact includes not only the electricity or fuels used during the product's lifecycle, but also the upstream energy required to obtain and process these fuels, and the embodied energy of materials which would be released if burned. PED is expressed as the net calorific value of energy demand from non-renewable resources (e.g. petroleum, natural gas, etc.). Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account.

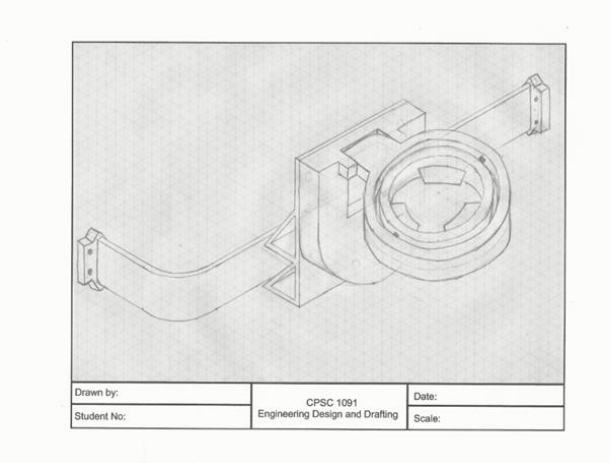
Water Eutrophication - When an over abundance of nutrients are added to a water ecosystem, eutrophication occurs. Nitrogen and phosphorous from waste water and agricultural fertilizers causes an overabundance of algae to bloom, which then depletes the water of oxygen and results in the death of both plant and animal life. This impact is typically measured in either kg **phosphate equivalent (PO_4) or kg nitrogen (N) equivalent**.

Life Cycle Assessment (LCA) - This is a method to quantitatively assess the environmental impact of a product throughout its entire lifecycle, from the procurement of the raw materials, through the production, distribution, use, disposal and recycling of that product.

Material Financial Impact - This is the financial impact associated with the material only. The mass of the model is multiplied by the financial impact unit (units of currency/units of mass) to calculate the financial impact (in units of currency).

Learn more about Life Cycle Assessment

Appendix H)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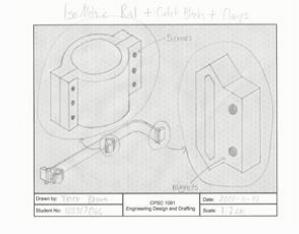
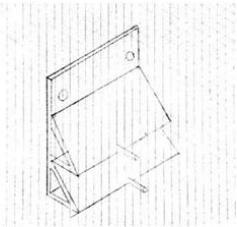
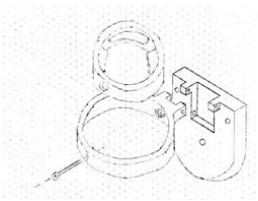
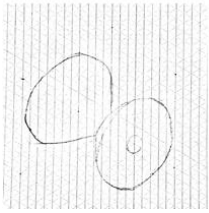
Student No:
CPSC 1091
Engineering Design and Drafting
Date:
Scale:



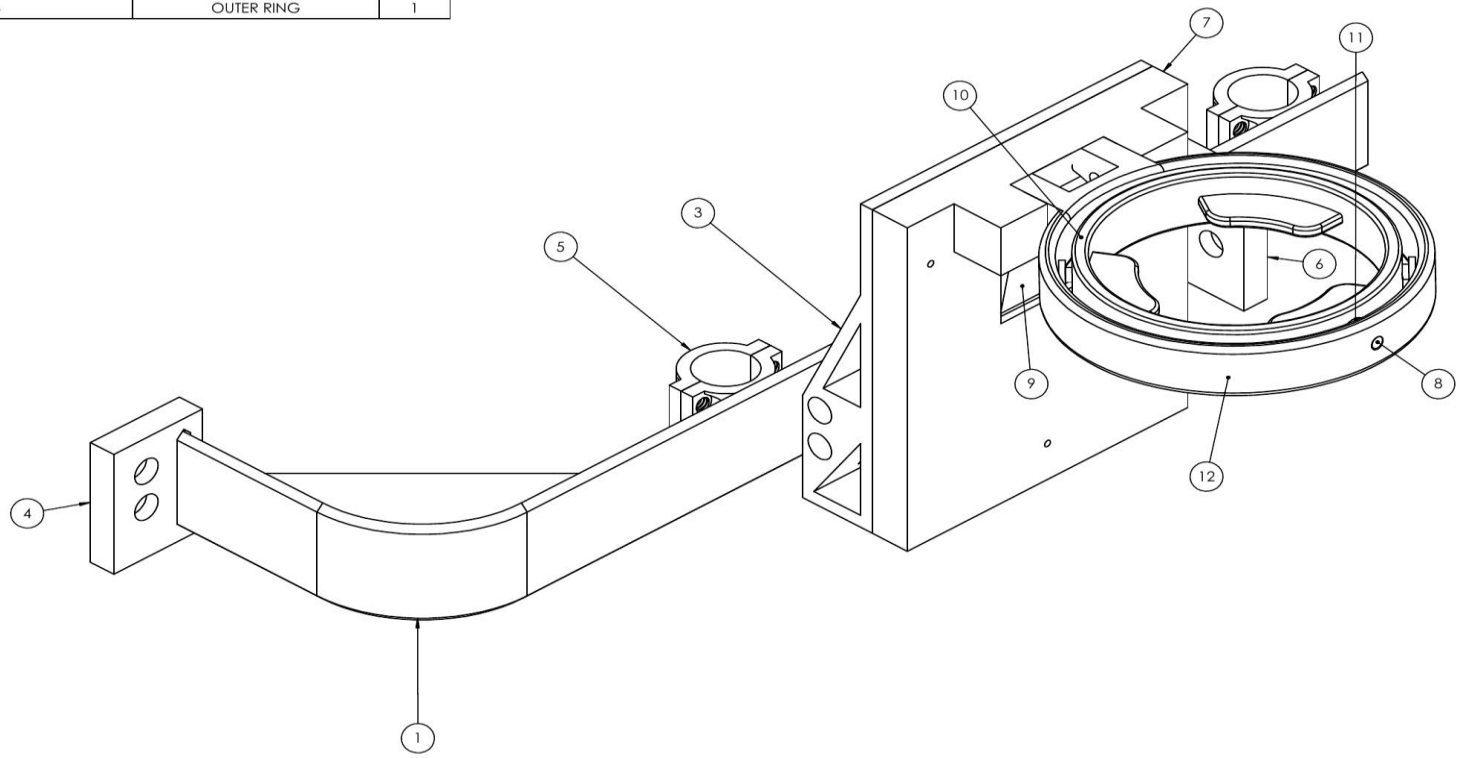






Appendix I)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	R1	RAIL	1
2	R2	WHEEL	2
3	R3	RAIL CAR	1
4	R4	CATCH BLOCK FRONT	1
5	R5	OUTER CLAMP	2
6	R6	CATCH BLOCK BACK	1
7	C1	BASE	1
8	C2	10MM SMALL PIN	4
9	C3	SUPPORT	1
10	C4	INNER RING	1
11	C5	BEARING	2
12	C6	OUTER RING	1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY | USED ON
APPLICATION
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	Hamza I.	21-11-20
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

TITLE: Rail + Cupholder

SIZE	DWG. NO.	REV
C	Assem #1	

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

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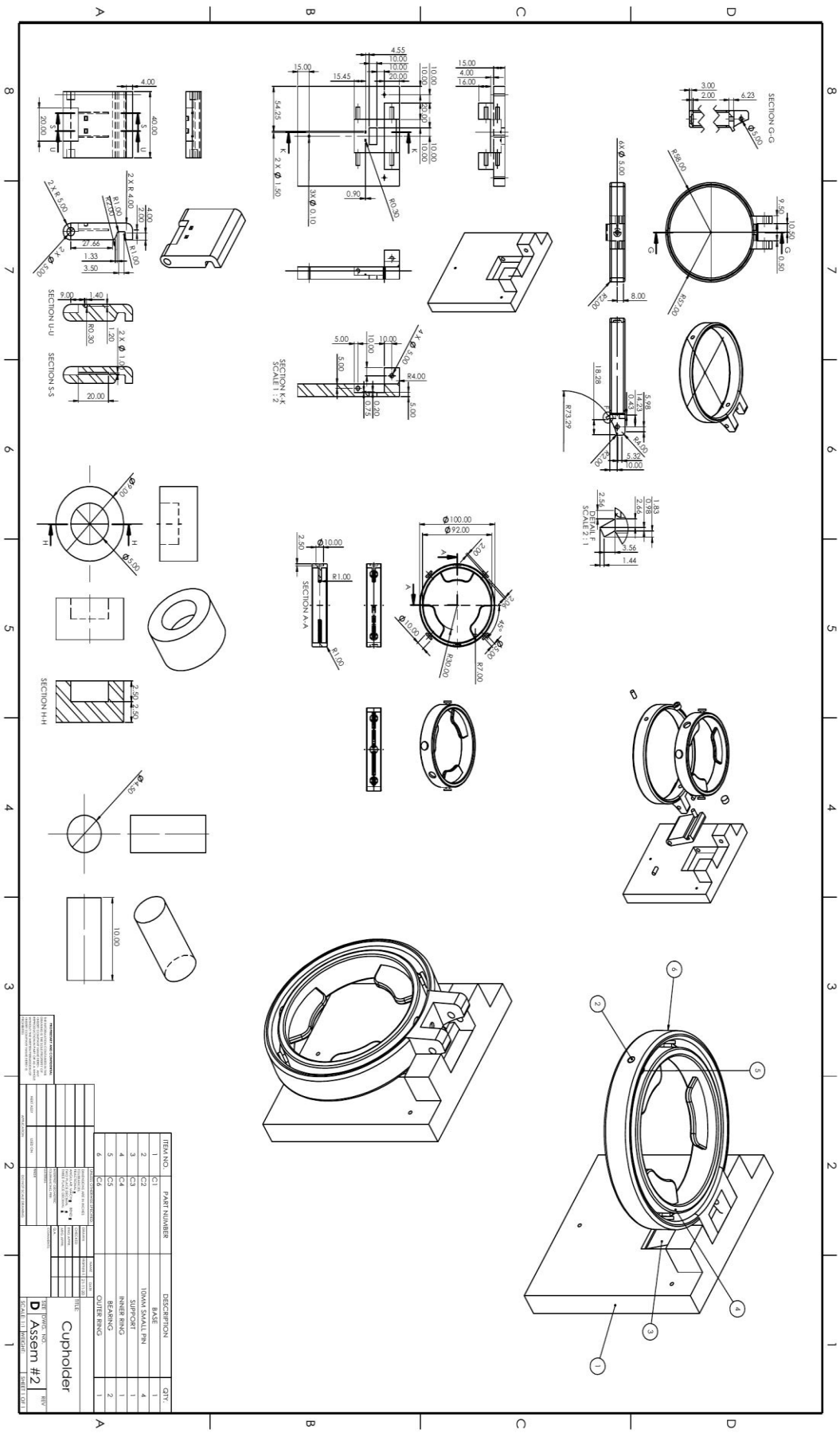

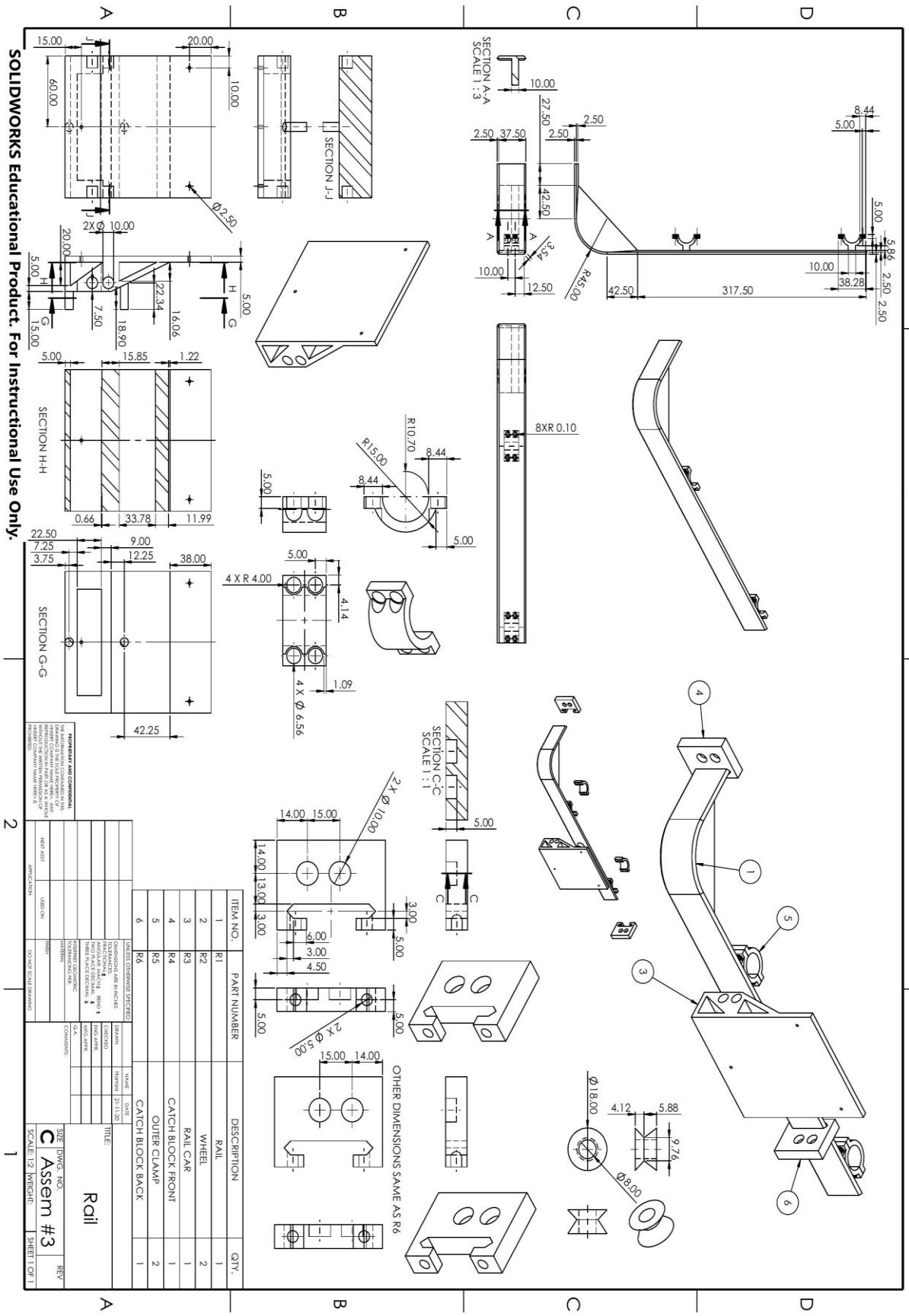

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	R1	RAIL	1
2	R2	WHEEL	2
3	R3	RAIL CAR	1
4	R4	CATCH BLOCK FRONT	1
5	R5	OUTER CLAMP	2
6	R6	CATCH BLOCK BACK	1