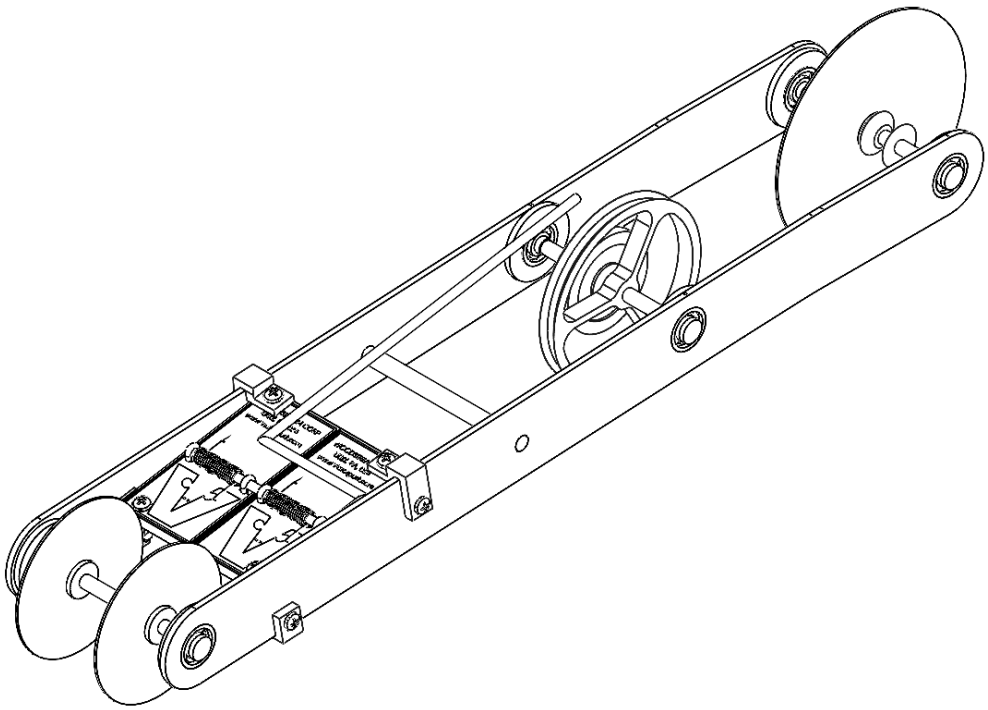
Mousetrap Car Technical Report



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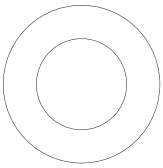
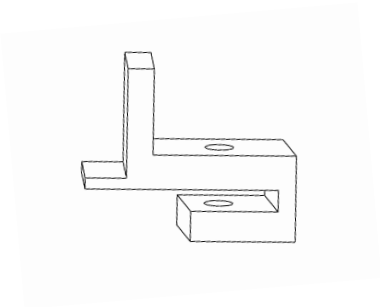
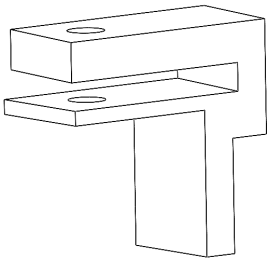
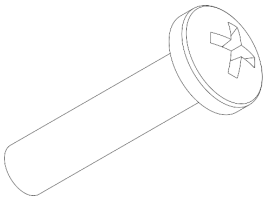
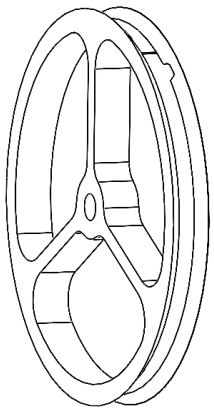
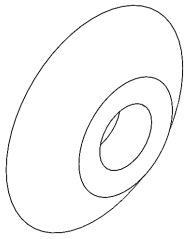
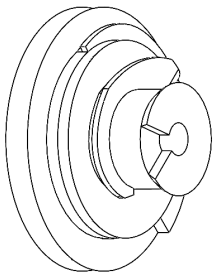
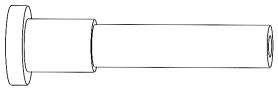
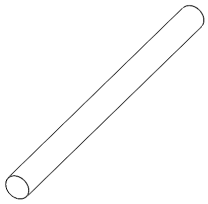
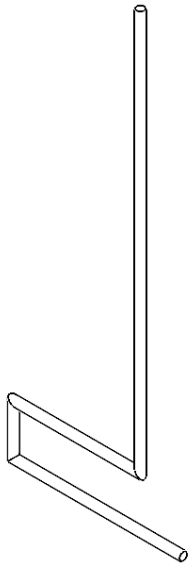
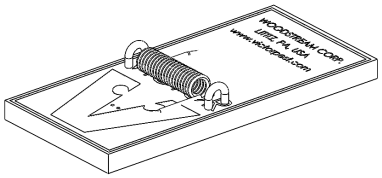
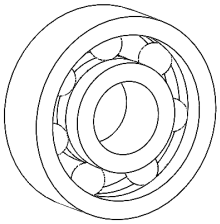
Problem Statement

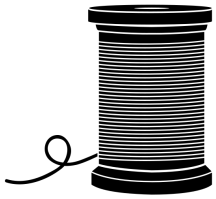
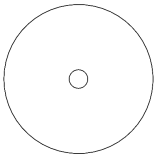
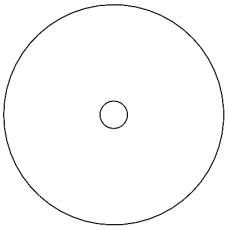
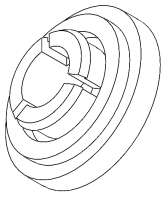
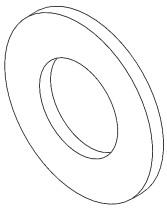
Design and build a mousetrap car that can travel the farthest distance possible. A maximum of two mouse traps are allowed and it must fit within a twenty-five dollar budget. The distance traveled by the car will be measured from the starting line to where the car makes a complete stop. The car must stay inside a three-foot track and should utilize mechanical advantage to travel as far along the track as possible with the available energy from the mousetrap lever.

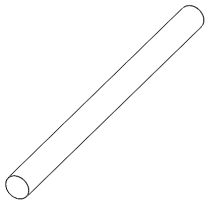
Parts List

Part	ID	Material	Image	Amount	Cost ($)
Frame	F1	Balsa		2	7.5
Bearing Support	F2	Balsa		6	0.48
Front Mousetrap Mounts	M1	Polylactic Acid		2	0.19
Back Mousetrap Mounts	M2	Polylactic Acid		2	0.18
M-32 ¾ Inch Screw	M5	Stainless Steel		8	0

Large Pulley	P1	Polylactic Acid		1	0.34
Small Pulley Guides	P3	Polylactic Acid		2	.11
Variable MA Shifter	P2	Polylactic Acid		1	.38
Axle Half	A1	Polylactic Acid		5	.08
Axle Quarter	A3	Polylactic Acid		1	.05

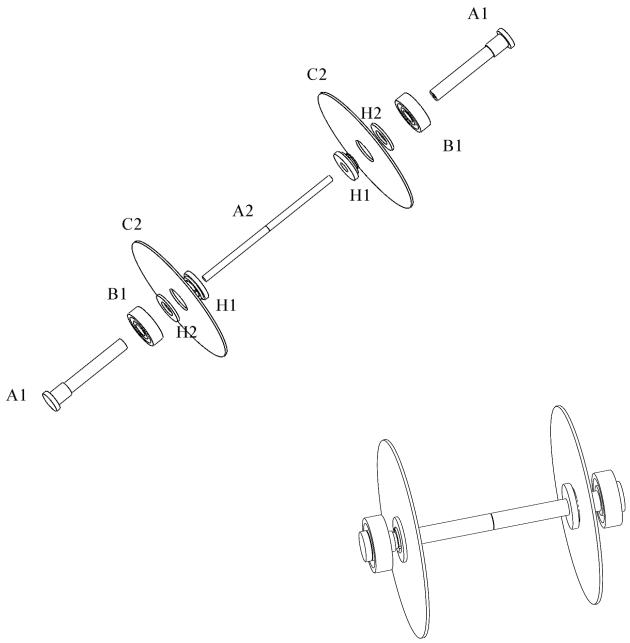
Axle Core	A2	Copper		3	0.5
Lever Arm	M4	Copper		1	2.5
Mousetrap	M3	Wood, Copper, Spring		2	2.00
Bearing	B1	High Carbon Steel		6	1.50

Fishing Wire	E1	Nylon		1	0.00
Cassette Tape	E2	Magnetic Coated Polyester		1	1.00
Mini CDs	C2	Polycarbonate		2	1.00
CDs	C1	Polycarbonate		1	.50
Hub Clip	H1	Polylactic Acid		3	.04
Hub Ring	H2	Polylactic Acid		3	.03

Wooden Support Beam	M6	Balsa		1	
Pneumatic Tubing	E3	Polyurethane		1	0

Assembly Instructions

Front Axle Assembly



a) Locate the following parts:
   i) Mini CD (C2) x 2
   ii) Hub Clip(H1) x 2
   iii) Hub Ring(H2) x 2
   iv) Axle Half(A1) x 2
   v) Axle Core(A2) x 1
   vi) Bearing(B1) x 2

b) Align a Hub Clip in the center of a mini CD

c) Snap a Hub Ring onto the other side

d) Repeat steps B and C with the remain CD

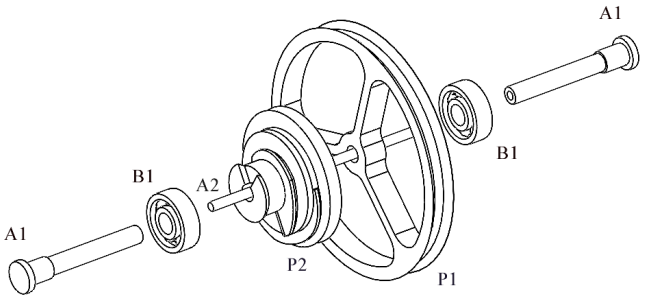
e) Slide a Bearing onto each Axle Half

f) Using a Hydraulic press, insert the Axle Core into the one of the Axle Halfs

g) Take the other Axle Half and press the CD and Hub assembly onto the very edge of the Axle Half

h) Press the Axle Half with the CD onto the Axle Core in the other Axle Half

Middle Gear Assembly

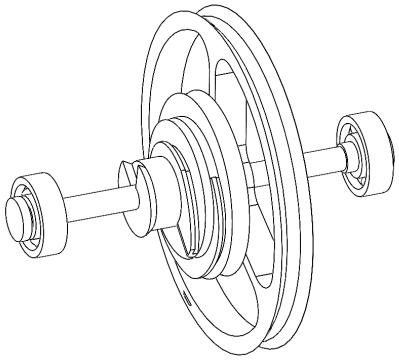


a) Locate the following parts
   i) Axle Half(A1) x 2
   ii) Axle Core(A2) x 1

iii) Bearing(B1) x 2

iv) Large Pulley(P1) x 1

v) Variable MA Shifter(P2) x 1



b) Slide a Bearing onto each Axle Half

c) Hydraulic press the Variable MA Shifter onto one Axle Half sloping outward

d) Hydraulic press the large pulley onto the edge of the remaining Axle Half

e) Using a Hydraulic press, insert the Axle Core into the one of the Axle Halfs

f) Press the Axle Half without the Axle Core onto the Axle Core in the other Axle Half

Back Axle Assembly

a) Locate the following parts:

i) Large CD (C1) x 1

ii) Hub Clip(H1) x 1

iii) Hub Ring(H2) x 1

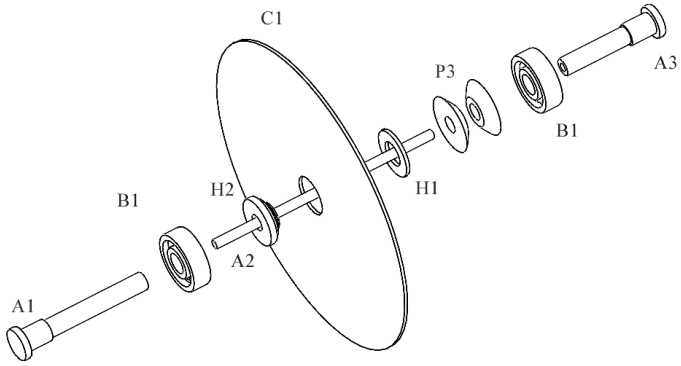
iv) Axle Half(A1) x 1

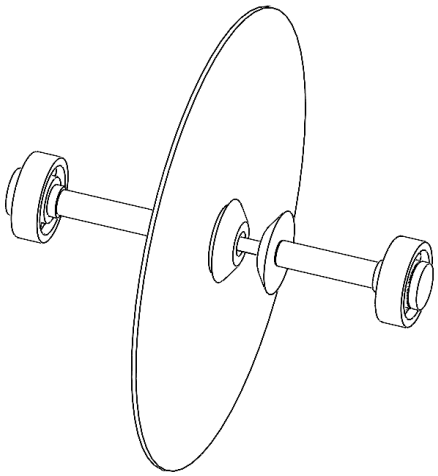
v) Axle Quarter(A2) x 1

vi) Axle Core(A2) x 1

vii) Bearing(B1) x 2

viii) Small Pulley Guides





b) Align the Hub Clip in the center of the CD

c) Snap the Hub Ring onto the other side

d) Slide a Bearing onto the Axle Half

e) Slide the other Bearing onto the Axle Quarter

f) Press a Small Pulley Guide onto the edge of the Axle Quarter(See Image Above)

g) Take the Axle Half and press the CD and Hub assembly onto the very edge of the Axle Half

h) Hydraulic press the remaining Small pulley guide onto the Axle half pushing the CD and Hub assembly down the Axle Half slightly

i) Using a Hydraulic press, insert the Axle Core into the Axle Half

j) Press the Axle Quarter onto the Axle Half with the Axle Core

Mousetrap Assembly

a) Locate the following parts:

   i) Mousetrap(M3) x 2

   ii) Lever Arm(M4) x 1

   iii) Front Mousetrap Mount(M1) x 2

   iv) Back Mousetrap Mount(M2) x 2

   v) M-32 Screw(M5) x 4

b) Disassemble the standard Mousetrap by taking out the U Hooks and removing the original lever arm

c) Slide the Lever Arm(from this kit) through the springs and both Mouse Traps - Note the orientation of the Lever Arm when with the springs are extended

d) Use an M-32 Screw to screw a Front Mousetrap Mount onto the Mousetrap from the bottom - Note the orientation using the screw holes on the side of the V

e) Repeat Step d

f) Use an M-32 Screw to screw the Back Mousetrap Mount onto the Mousetrap from the top - Note the orientation using the screw holes opposite to the side of the V

Frame Assembly

a) Locate the following parts/subassemblies:
   i) Front Axle Assembly
   ii) Middle Gear Assembly
   iii) Back Axle Assembly
   iv) Mousetrap Assembly
   v) Frame(F1) x 2
   vi) Bearing Support(F2) x 6
   vii) M-32 Screws(M5) x 4
   viii) Wooden Support Beam(M6) x 1
   ix) Cassette Tape(E2) x 1
   x) Fishing Wire(E1) x 1
   xi) Pneumatic Tubing(E3) x 1
b) Using superglue, glue 3 Bearing Supports around the 3 pre cut holes in the frame
c) Repeat Step B on the other frame but on the opposite side - This will allow the bearing supports to sit on the inside of the frame when fully assembled
d) Press the Back Axle Assembly into the holes specified in image below
e) Press the Middle Gear Assembly into the holes specified in image below
f) Screw the Mousetrap Assembly into the frame using the precut holes as guides
g) Press the Front Axle Assembly into the frame

h) Press the Wooden Support Beam into the final hole

i) Tie one end of the Fishing Wire onto the Pneumatic Tubing

j) Slide the Pneumatic Tubing onto the end of the Lever Arm

k) Tie the other end of the Fishing Wire to the Middle Gear Assembly as seen in image below

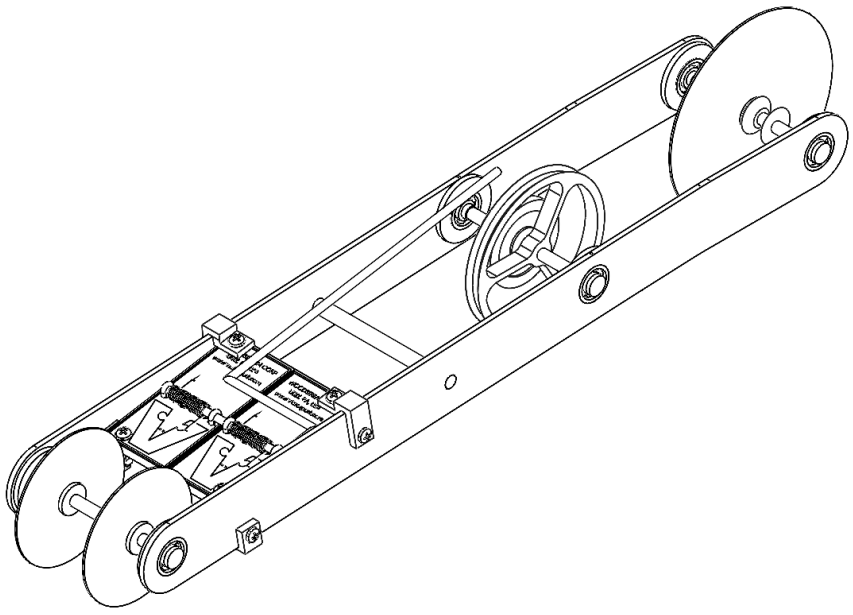
l) Spin the Middle Gear Assembly counterclockwise winding up the Lever Arm

m) Tape one end of the Cassette Tape to the revealed area on the copper lever from the Back Axle Assembly

n) Wind the Cassette Tape around Back Axle Assembly in the direction noted in image below

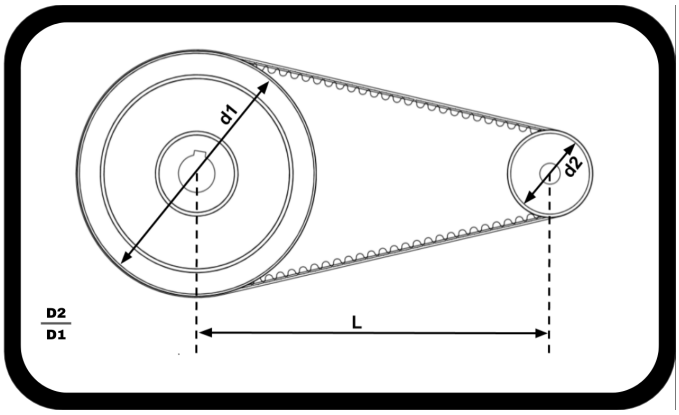
o) Tape the other end of the Cassette Tape to the top of the Large Pulley

p) Place the *Mousetrap Car* on the starting line and release it



Research

Mechanical Advantage



To kickstart this project, we studied mechanical advantage, especially in gear systems. Mechanical advantage is often used as a tool to trade effort for strength. For example, a ramp increases the distance required to move an object but inversely reduces the amount of force required at any given time to move the object upwards against gravity. Mechanical advantage is the ratio between output force and input force. This can be used in the mousetrap car project as the slow release of energy over a longer period of time reduces the energy released in other forms other than a forward mechanical motion.

Rotational Inertia

Inherently, by creating a design incorporating wheels, a major force we had to overcome was rotational inertia. Rotational inertia is a value of any object that rotates that determines how difficult it is to change the rotational velocity around a given axis. The main determinant of this value is the mass of the object and how that mass is distributed around the rotational axis. This property increases for every wheel that is added to a design. One way to combat this issue, as seen in many record holders, was either a thin or small wheel, or if opting for a large wheel, cutouts to lower the total mass and thus the rotational inertia. Many record-holding designs also opted for three wheels instead of the usual four.

Distance Cars

Mousetrap Cars generally compete in one of two formats, although there are some variations in the challenges from competition to competition. The main two formats are speed cars and distance cars. While speed cars rely on releasing as much of a mousetrap's energy as possible at once to achieve the highest single speed, distance cars take advantage of a slow energy release over a long period of time to get the most distance covered as possible. For distance cars to be successful, the mechanical advantage should be as high as possible to ensure the wheels cover the maximum ground they can. To do this there are a number of options that can be taken, such as increasing the size of the drive wheel, decreasing the size of the drive axles, or increasing the size of the lever arm, all in order to make the car as slow as possible to increase total pulling distance.

Previous Records

One resource we used to research various ways of creating our mousetrap car was looking into previous record-holding designs. The record-holding car for distance currently utilized a mechanical pulley system with cassette tape attached to the drive axle to simulate a much longer lever arm than was present by coiling it around a middle gear to increase the mechanical advantage, and was able to achieve a distance of 182 meters (597 feet). Other cars opted to keep it simpler and utilize a lengthy frame and long lever arm to keep the design barebones and lightweight while maximizing the possible mechanical advantage. Another design choice seen in many records was the use of CDs as wheels to decrease surface area and friction as well as some weight reduction compared to larger wheels.

Gears

One of the main obstacles we needed to overcome, as previously stated, was rotational inertia. A reason that you can't just make your wheel infinitely large or lever arm infinitely long to increase mechanical advantage and make a better car is that the mousetrap still needs to have enough power to drive its weight. A way to combat this problem we found was a gear design in which the fishing line used to pull the mousetrap would be wrapped around different-sized gears that would change the mechanical advantage during the run. This would allow for more power to be used when it begins to overcome rotational inertia and then decrease to a lower mechanical advantage when it is in motion to increase its pulling distance.

Design/Development

Pulley System

Our original mousetrap car drafts featured design elements similar to that of traditional mousetrap cars like four wheels made of wood and a basic body with most mechanical advantage coming from the wheel-to-axle ratio and the lever arm. We experimented with belt drive systems and pulleys to try and increase our mechanical advantage without our weight going up linearly and eventually settled on a pulley system.

Gear System

Our Gear System incorporated three different levels that would act as a way to make our mechanical advantage adjustable and tailor it to the course environment. We added ramps connecting the gears for a smoother transition from gear to gear and placed them next to the main pulley driving the car. The gears were constructed from PLA because of how intricate the parts were and limited the infill to reduce weight.

Wheels

Although we experimented with wooden wheels, we decided upon CDs for our final. From our research, we found CDs were very common among mousetrap cars and found this was due to their low weight and low friction. Our design would have been fine with four standard CDs, but we realized we could use the small form factor mini DVDs to additionally decrease the weight of our car. Because we still wanted the mechanical advantage of the ratio between the axle and regular CD, we only chose to use mini DVDs for the front two wheels only.

Material Choice

Material Choice was a big topic of our drafting and designing process. Most cars from previous years chose plywood to provide a strong frame that wouldn't break from the torque of the mousetraps. We chose balsa for the frame because it is lightweight and we needed as much weight reduction as possible as this would reduce the rotational inertia that would need to be overcome in testing. For most of the other parts, PLA plastic was chosen because we could make intricate and complex parts like our gear and pulley systems at a relatively low cost and not too much weight.

Axle Design

Our axles were created with the intent of structural integrity and low diameter. As we had extra unused copper rodding, we used those for the base of the axles and press-fit PLA overtop to allow for different diameters to fit our bearings and parts. This composite was durable and provided the structure we needed without increasing the diameter too much.

Data Collection

- Adjustments on Test Runs

Run 1:

Distance 78 feet Time Elapsed: 45 sec. Speed: 1.733 ft/s

Run 2:

Distance: 38 feet Time Elapsed: 21 sec. Speed: 1.810 ft/s

Run 3:

Distance: 51 feet Time Elapsed: 25 sec. Speed: 2.04 ft/s

Conclusion

Overall, I think we could have done better with this project. While our mousetrap car did meet the required criteria and achieve the necessary run length of 50ft, I believe that with a couple more adjustments, we could've consistently run the length of the atrium(~140ft). In every official test run, the mousetrap car ran out of bounds. At the beginning of the project, it heavily turned right but by the time the official test runs occurred, we had drastically decreased this allowing it to run much straighter. However, our positioning at the starting line did not reflect these changes and was not properly calibrated.

With the knowledge gained from this project, we have developed a number of potential changes that would allow further improvements to this design addressing direction, bowing of the frame, and the cassette pulley among other things. These changes are further elaborated in the diagrams below this section.

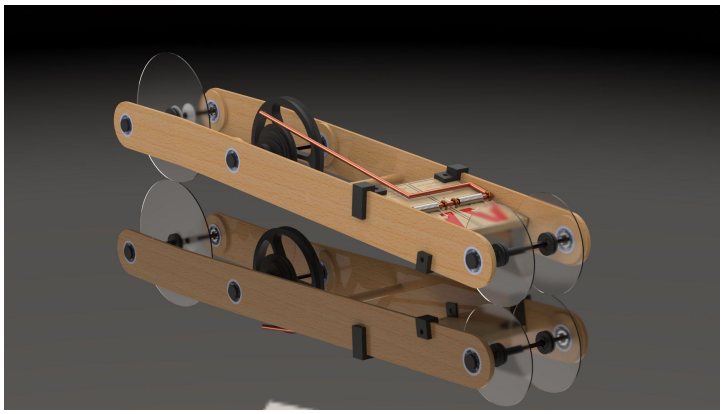
On the bright side, we did many things well. Our team effectively managed our time and had a mousetrap car built well ahead of schedule. This allowed a significant amount of testing and a revised design for our Variable MA Shifter(pictured with the reflected changes). With more testing, this contraption has a lot of potential as it would allow for the preprogramming of variable torques. This is especially useful as it would be able to adjust the torque to match the dips and rises in the floor of the track. The virtual CAD design allowed us to properly design the mousetrap while keeping the design well within cost specifications.

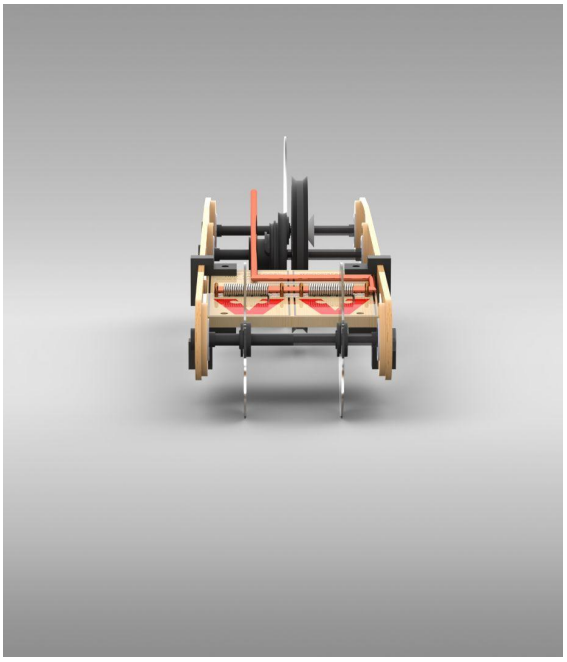
References

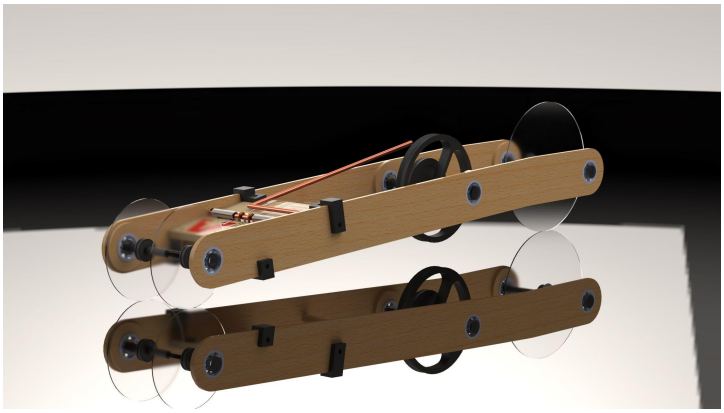
Mousetrap car products. Mouse Trap Cars | Distance Records | Doc Fizzix. (n.d.). Retrieved May 4, 2023, from https://www.docfizzix.com/topics/records/Mouse-Trap-Vehicles/distance-vehicles.shtml

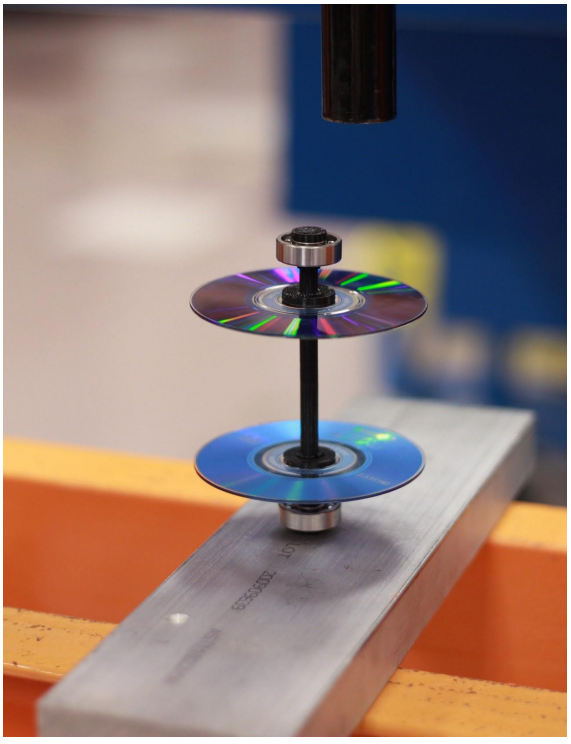
Gear. Gear - Energy Education. (n.d.). Retrieved May 4, 2023, from https://energyeducation.ca/encyclopedia/Gear#:~:text=Gears%20are%20of%20common%20use,the%20wheels%20efficiently%20and%20safely.

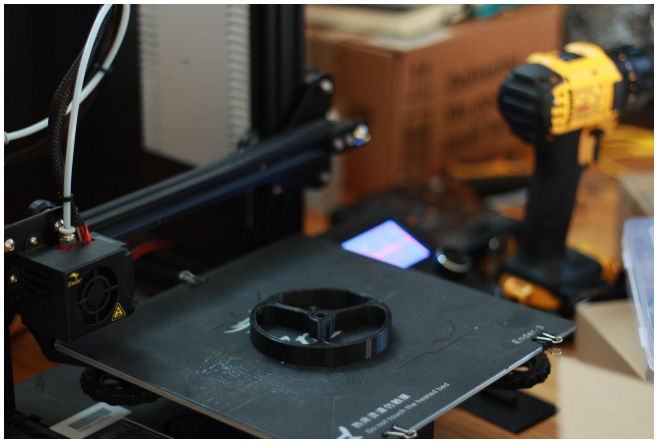
Photo Journal









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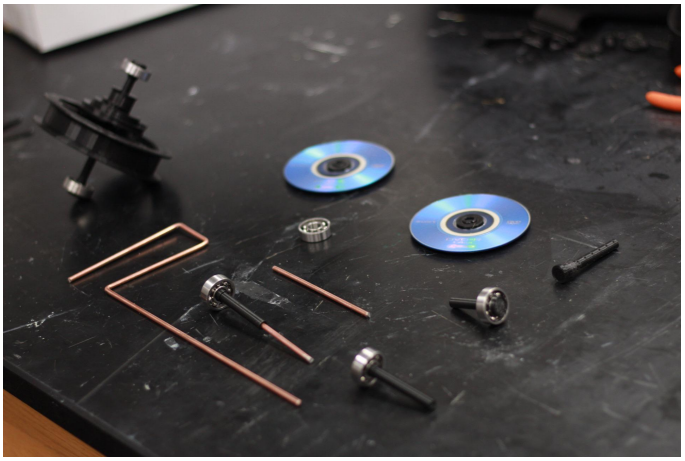
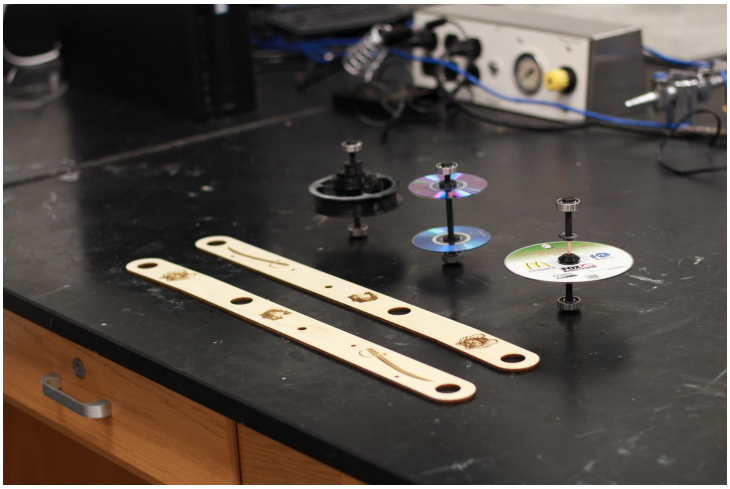
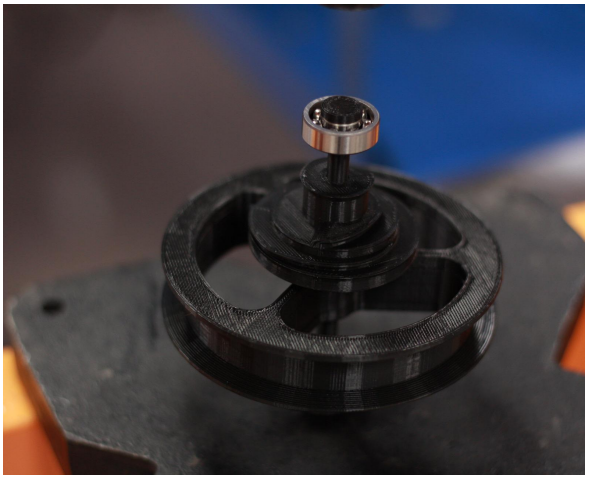
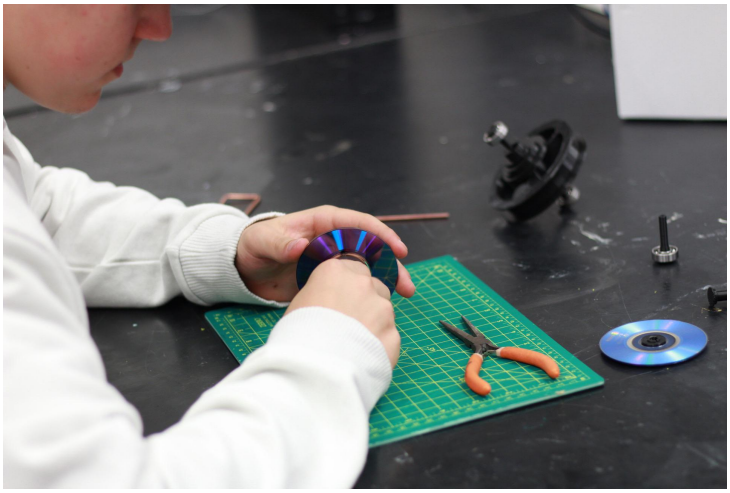
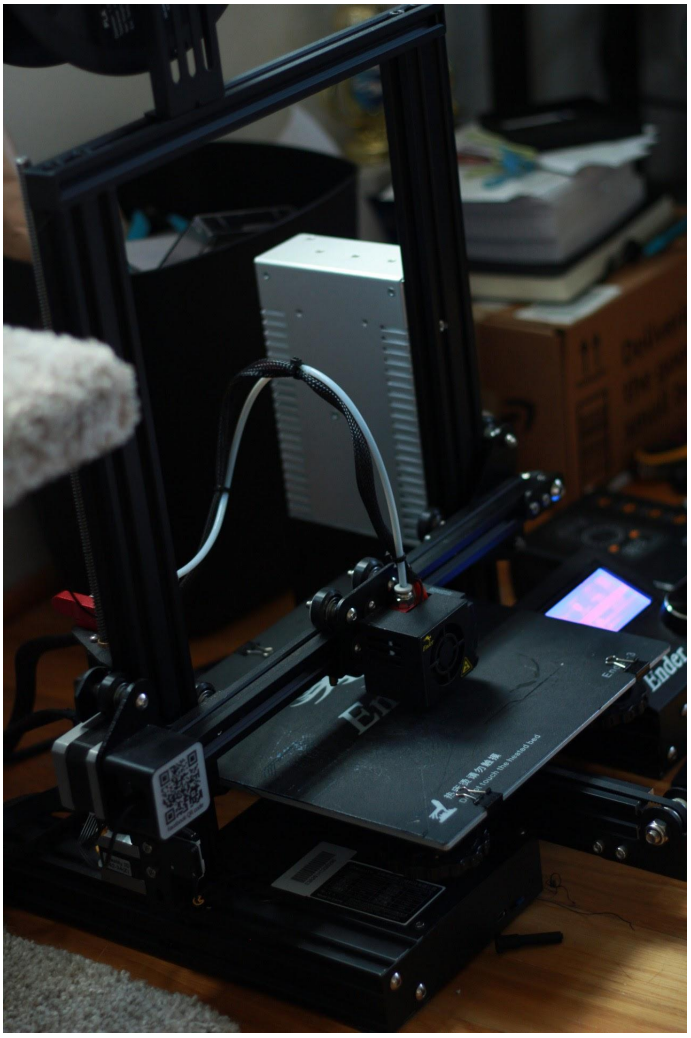
VICTOR

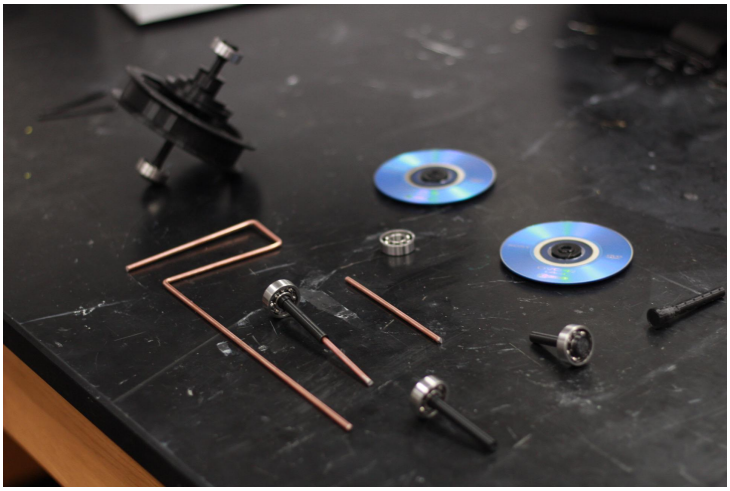


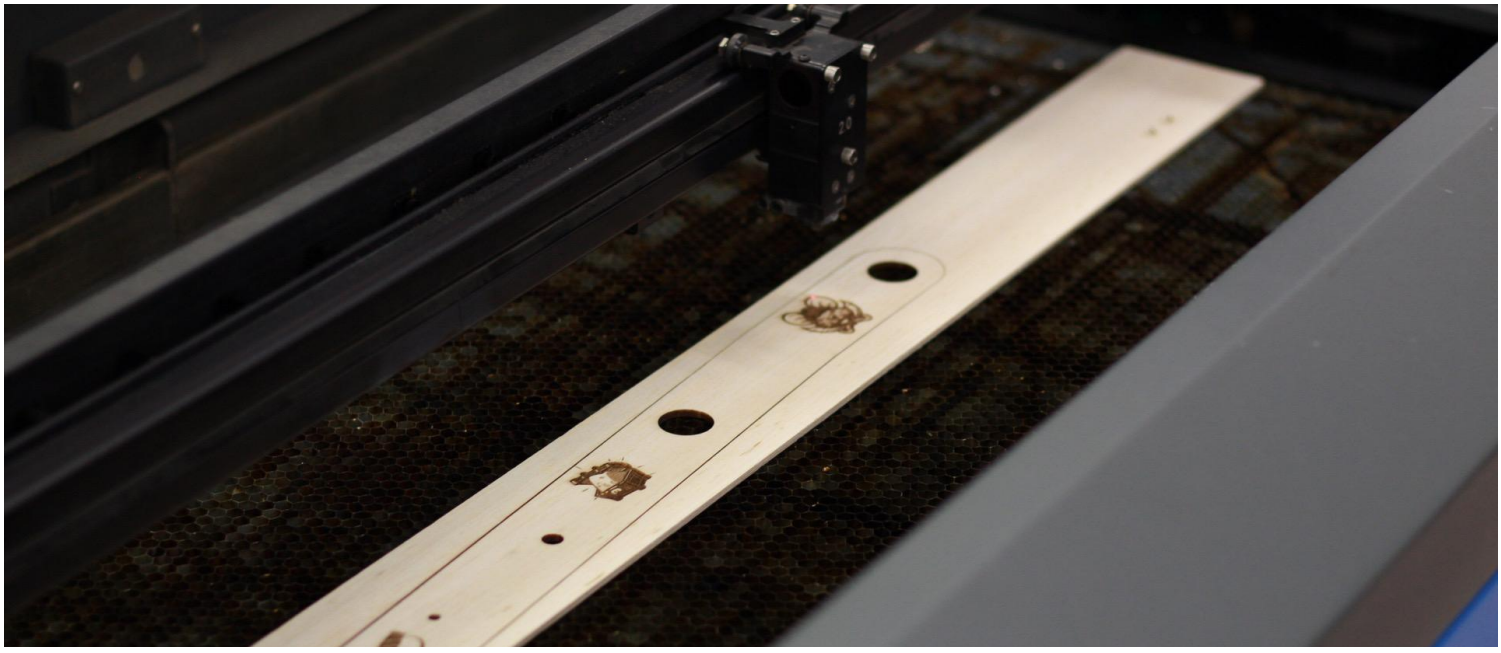


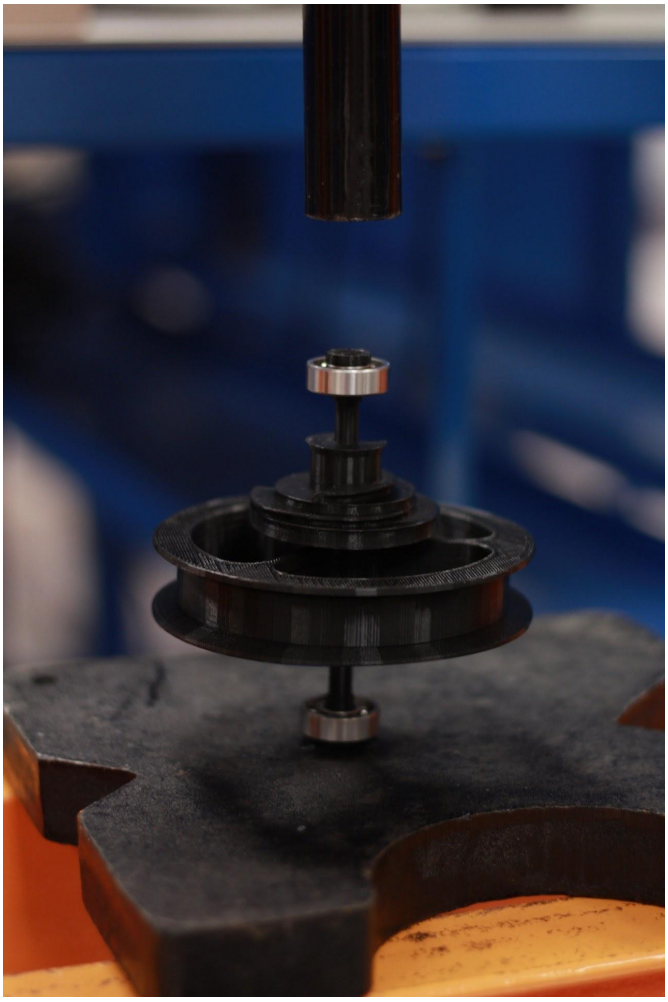


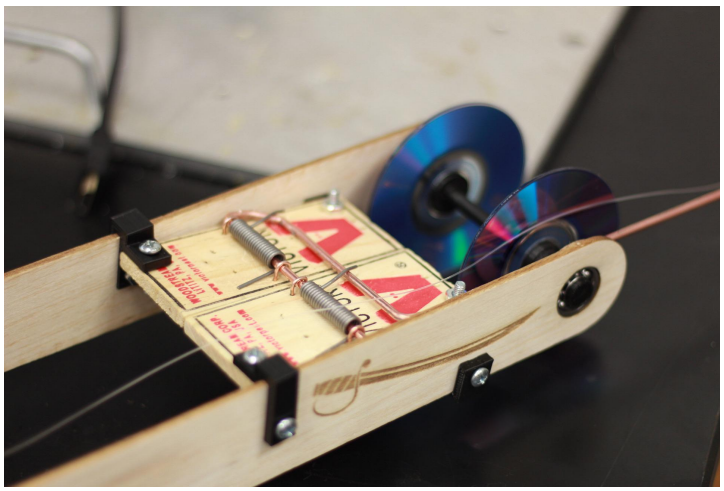


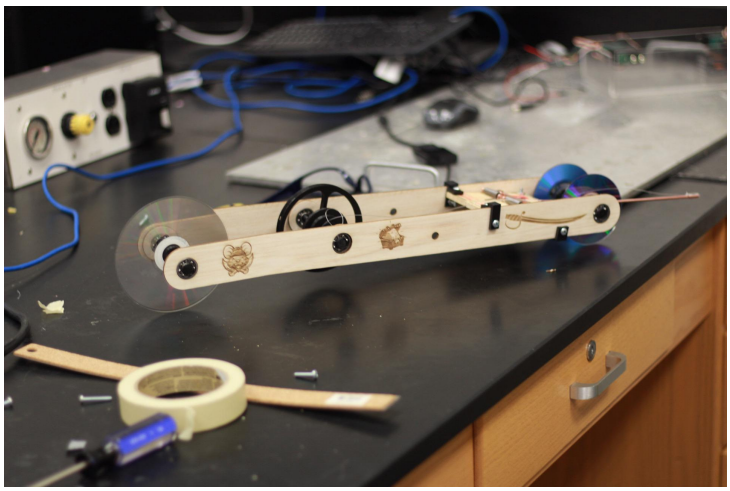


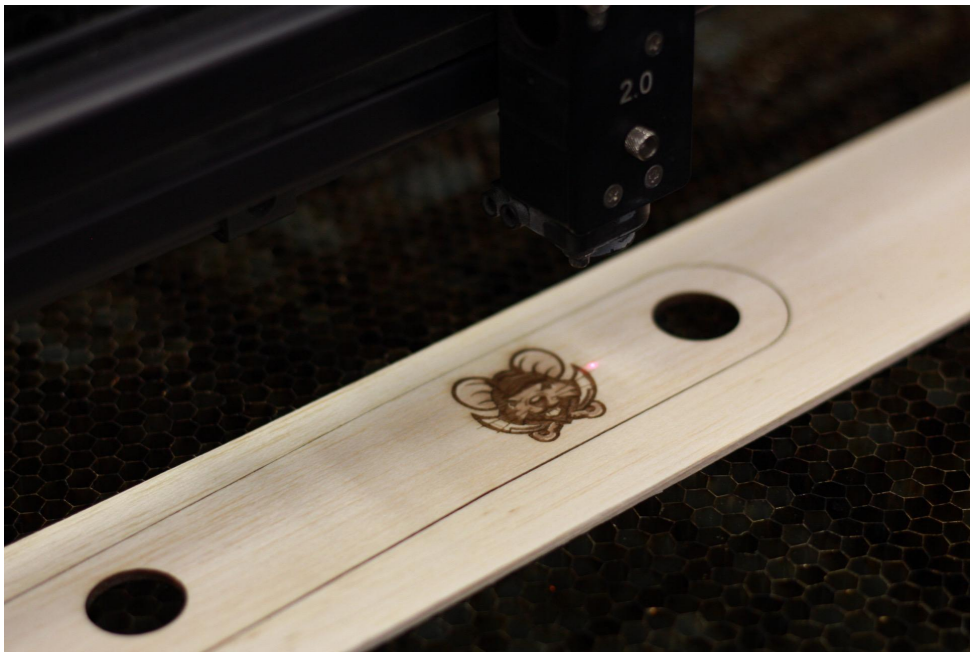








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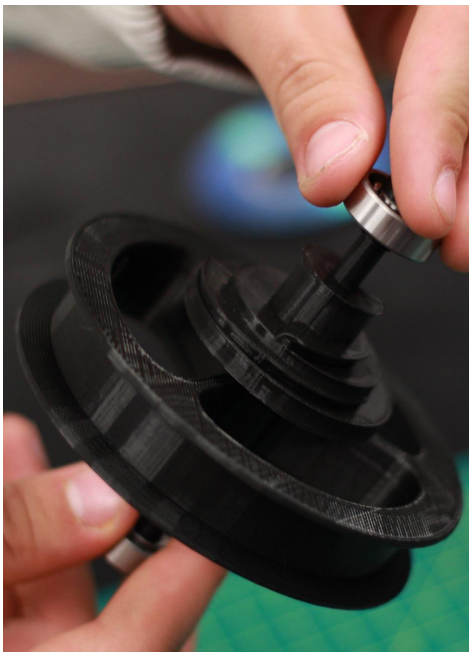
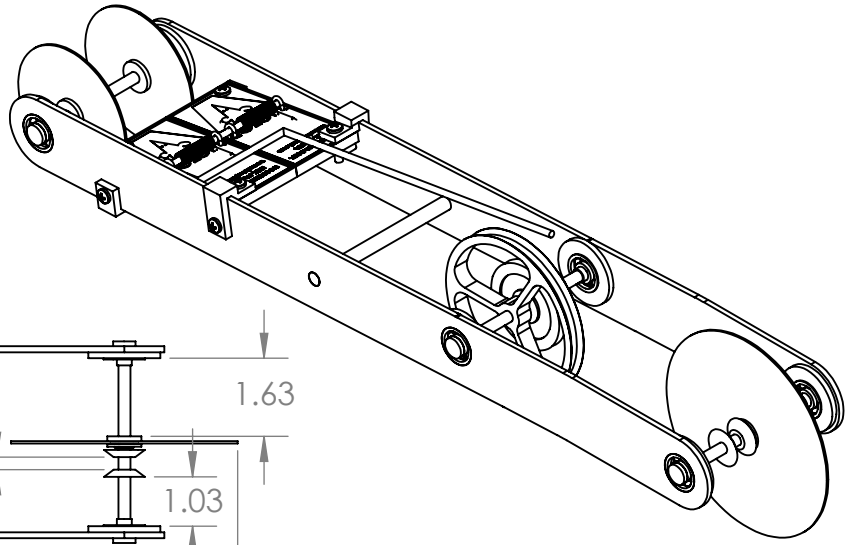
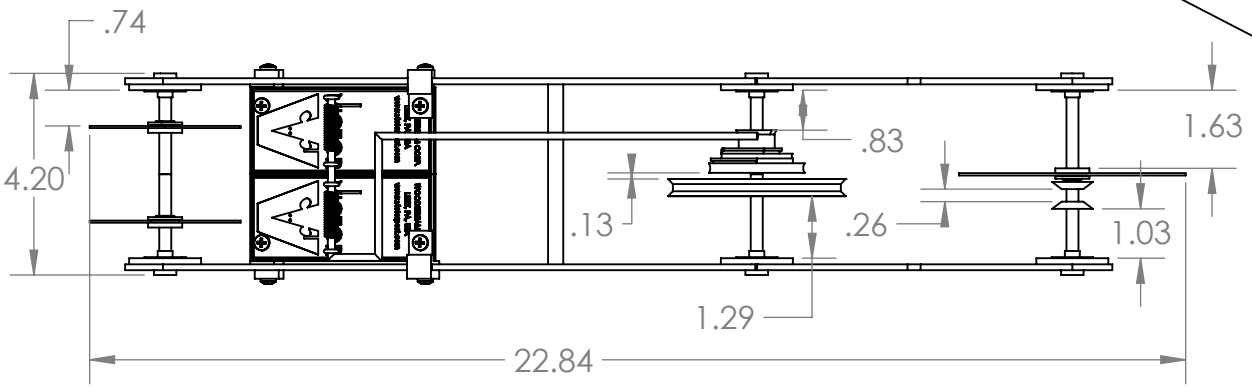
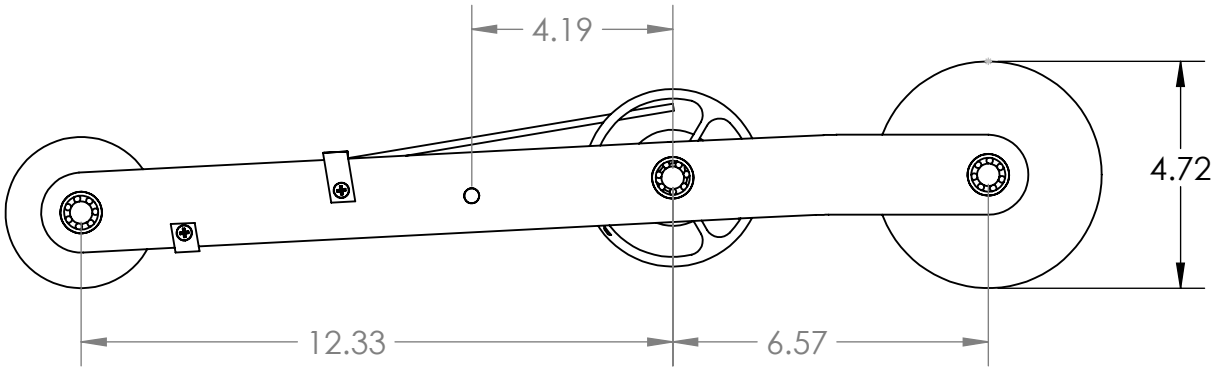
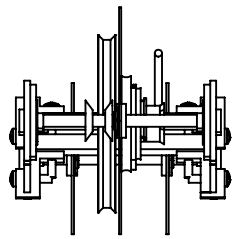




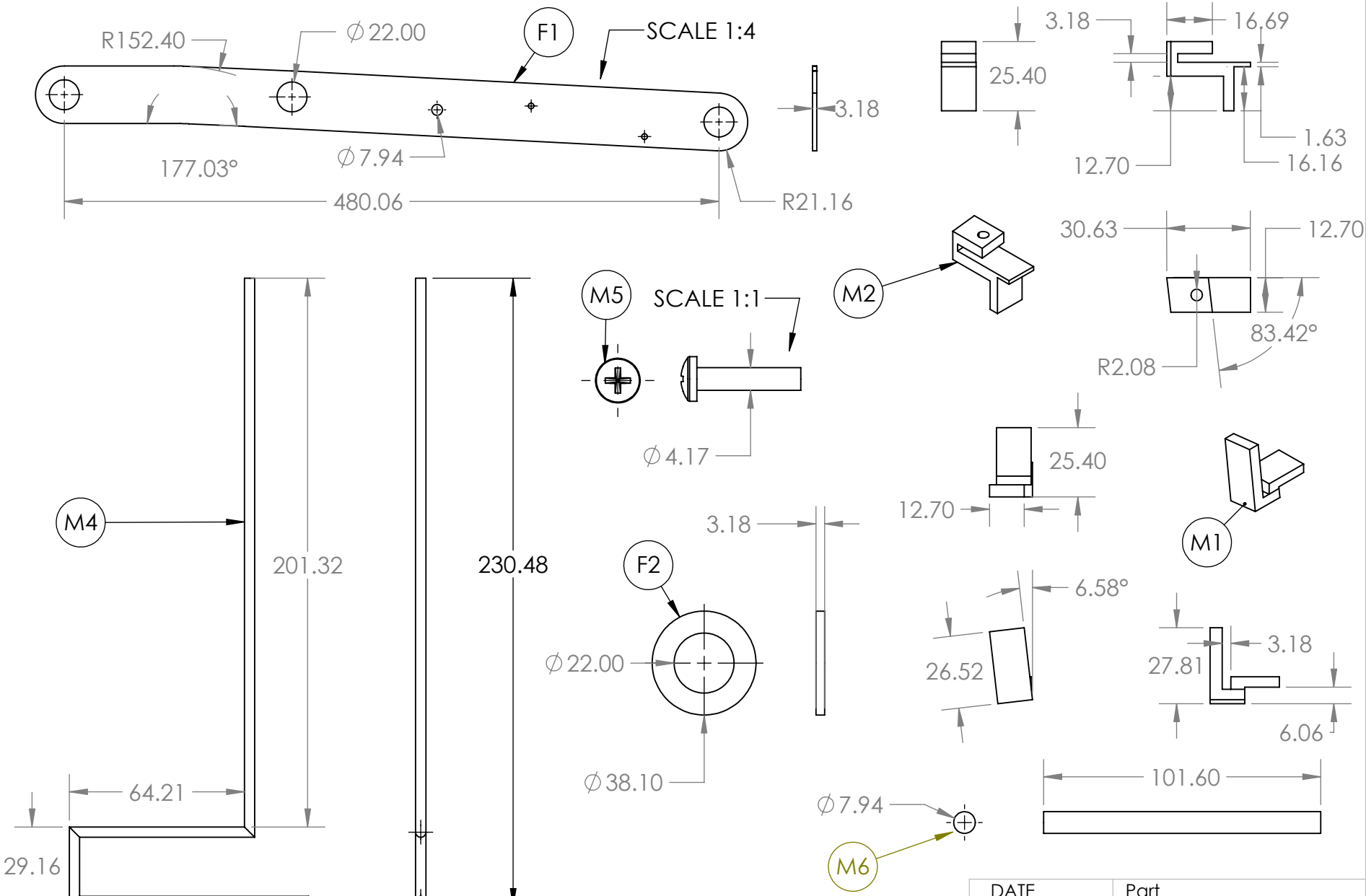






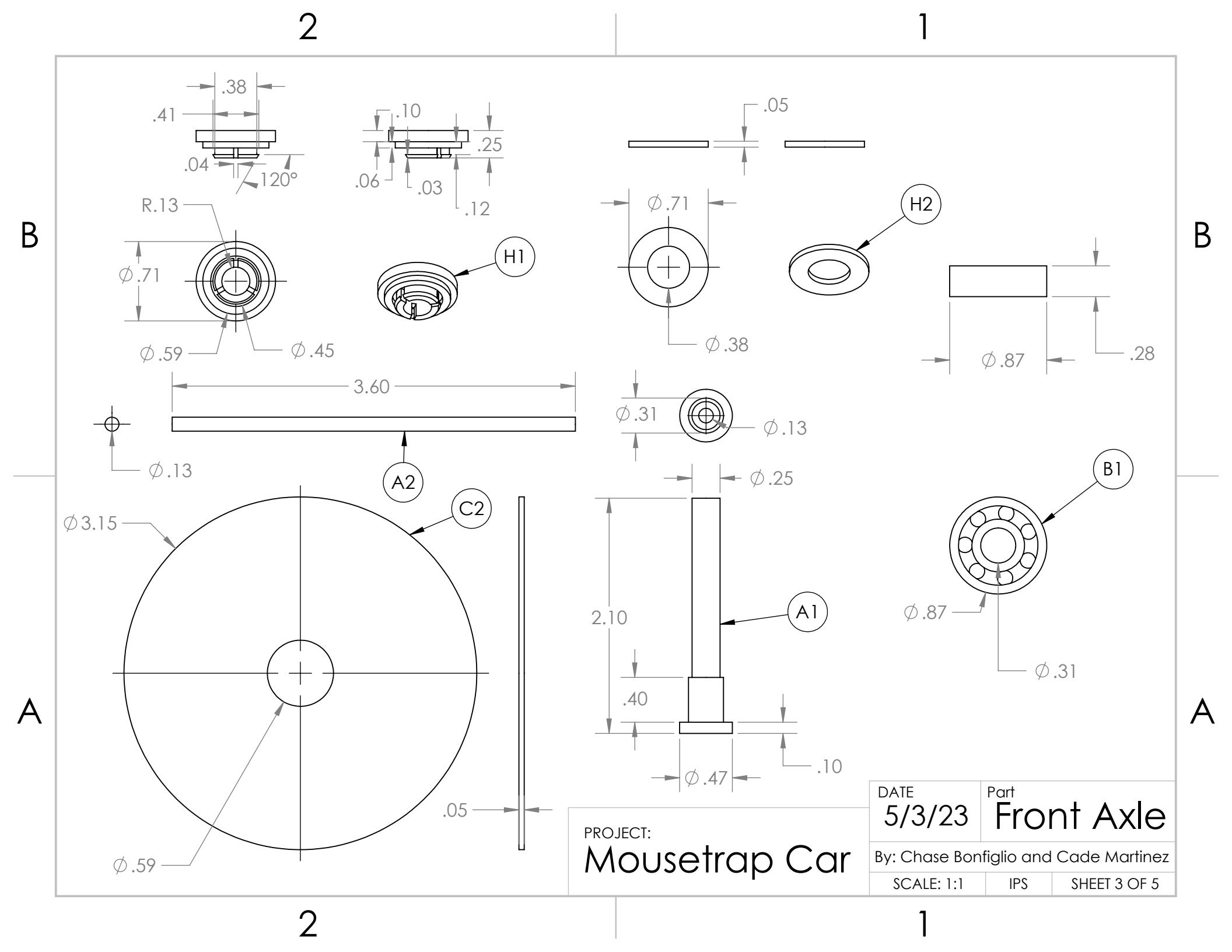
PROJECT:
Mousetrap Car

DATE	Part
5/3/23	Assemby
By: Chase Bonfiglio and Cade Martinez	
SCALE: 1:4	IPS	SHEET 1 OF 5



PROJECT:
Mousetrap Car

DATE	Part
5/3/23	Main Parts
By: Chase Bonfiglio and Cade Martinez	
SCALE: 1:1	IPS	SHEET 2 OF 5


.38
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120°
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R.13
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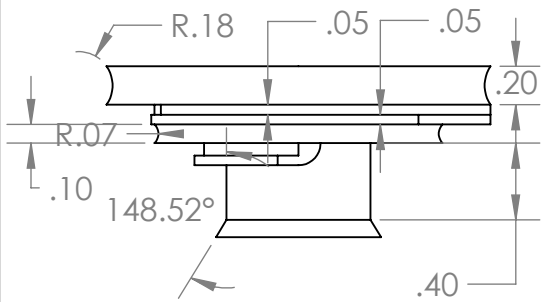
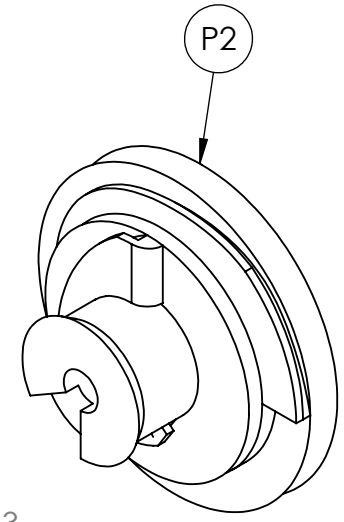
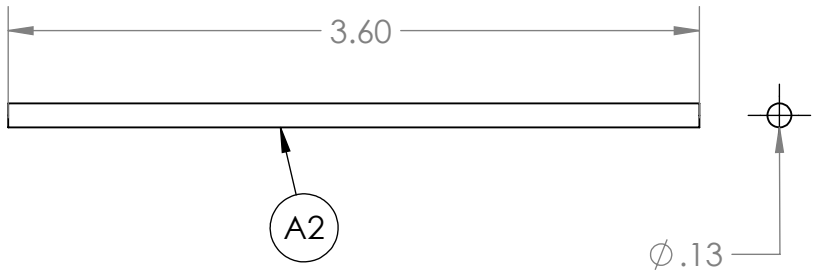
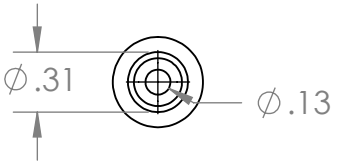
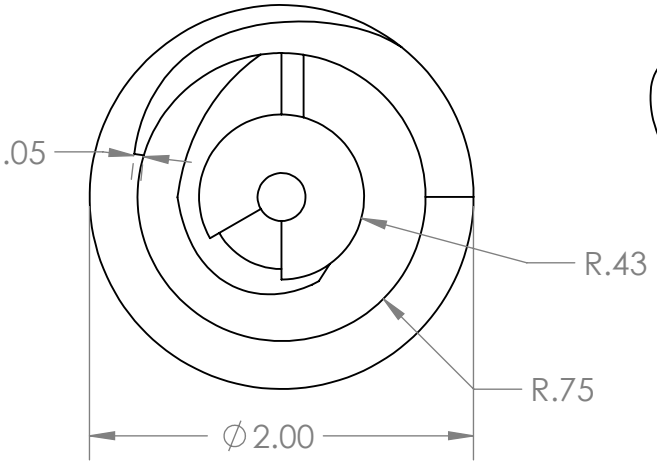
∅.59
∅.45
H1
∅.71
H2
∅.38
∅.87
.28
3.60
∅.13
A2
∅.31
∅.13
∅.25
C2
∅3.15
2.10
A1
B1
∅.87
∅.31
.40
.10
∅.47
.05
∅.59
PROJECT:
Mousetrap Car
DATE
5/3/23
Part
Front Axle
By: Chase Bonfiglio and Cade Martinez
SCALE: 1:1
IPS
SHEET 3 OF 5

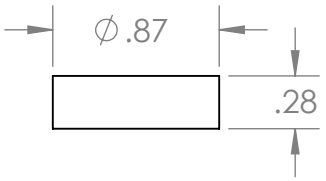


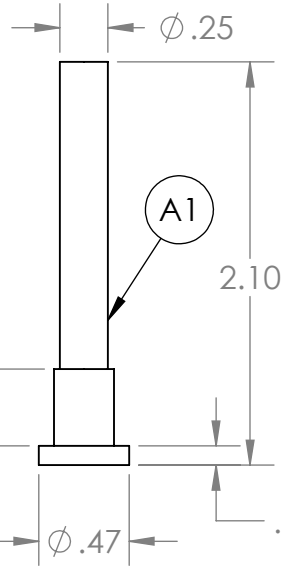


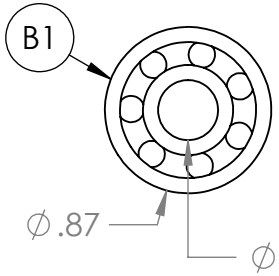


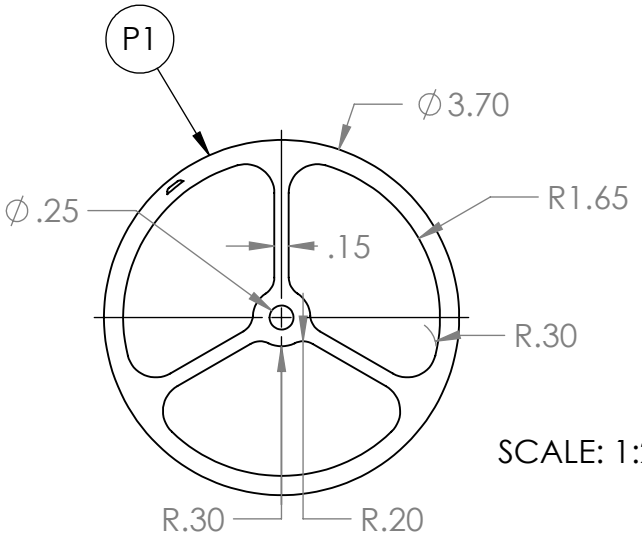


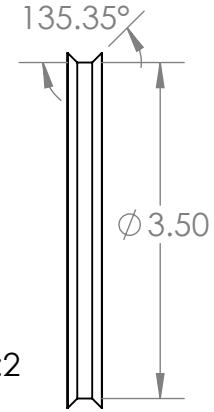








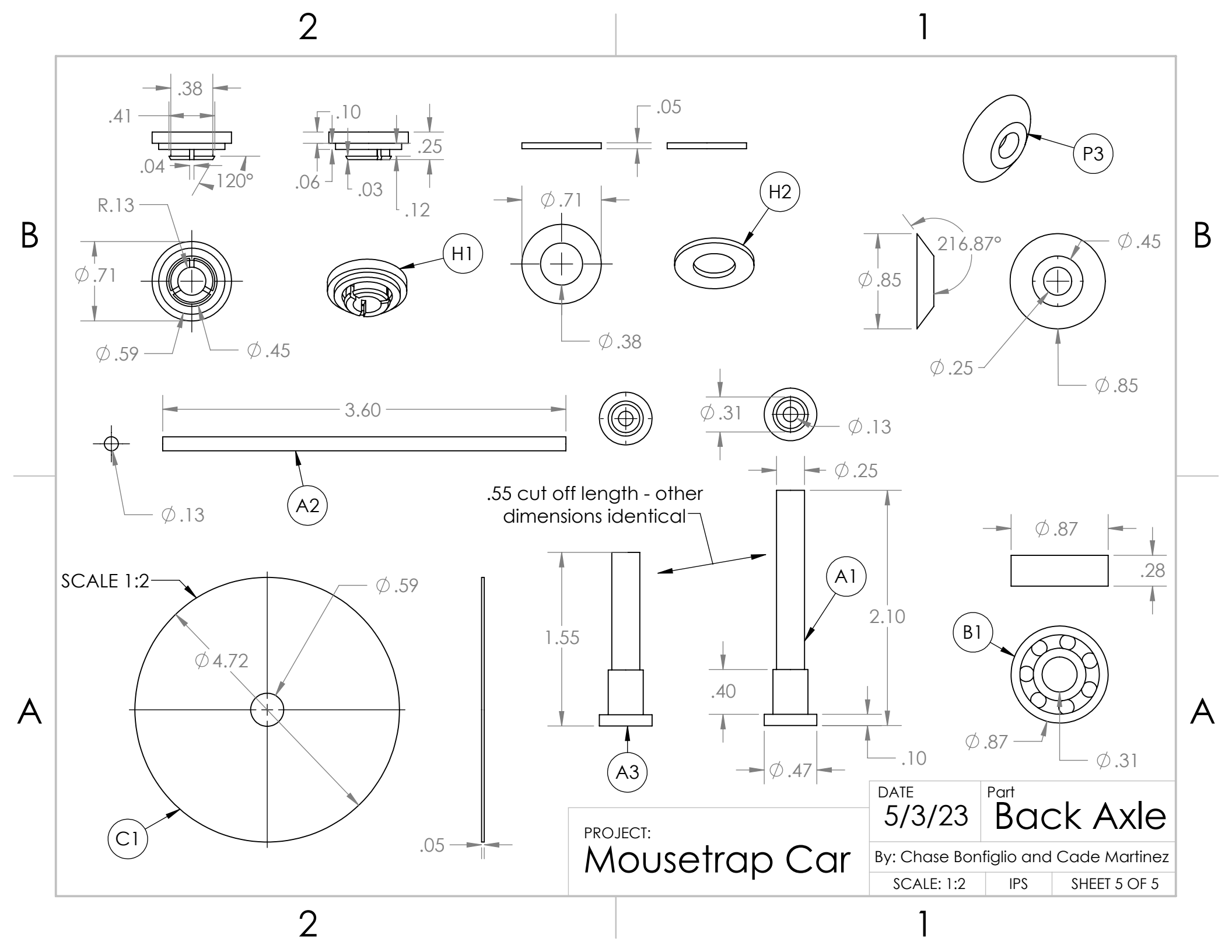




SCALE: 1:2

PROJECT:
Mousetrap Car

DATE	Part
5/3/23	Middle Axle
By: Chase Bonfiglio and Cade Martinez	
SCALE: 1:1	IPS	SHEET 4 OF 5


.38
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120°
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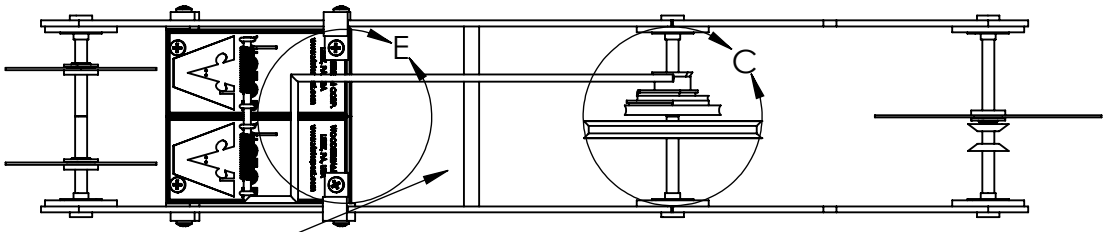
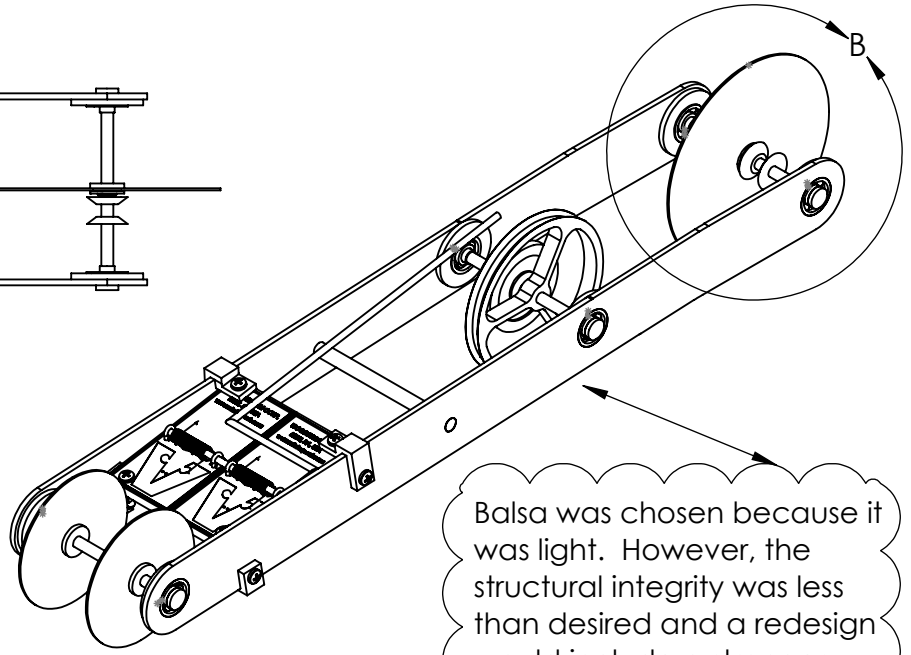
.12
.05
P3
R.13
∅.71
∅.59
∅.45
H1
∅.71
H2
∅.38
216.87°
∅.85
∅.45
∅.25
∅.85
3.60
∅.13
A2
∅.31
∅.13
∅.25
.55 cut off length - other dimensions identical
A1
2.10
1.55
.40
.10
∅.47
A3
∅.87
.28
B1
∅.87
∅.31
SCALE 1:2
∅.59
∅4.72
C1
.05
PROJECT:
Mousetrap Car
DATE
5/3/23
Part
Back Axle
By: Chase Bonfiglio and Cade Martinez
SCALE: 1:2
IPS
SHEET 5 OF 5

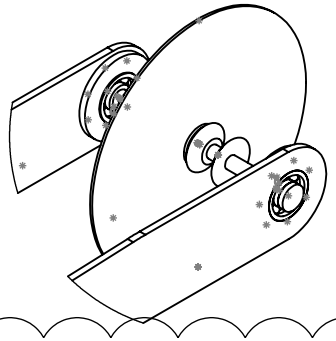


The wooden support beam used doesn't provide very much support. A redesign would include the removal of this for weight reduction or replacement closer to the back as that location had the most flex.

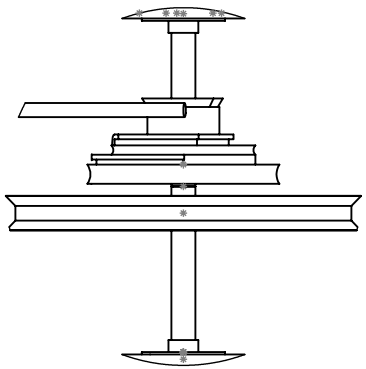


Balsa was chosen because it was light. However, the structural integrity was less than desired and a redesign would include a stronger material such as plywood or pine.

DETAIL B
SCALE 1 : 3

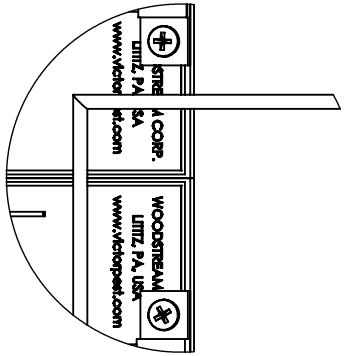


DETAIL C
SCALE 1 : 2



Our three wheel design was chosen to reduce weight. However, the combination of this with balsa wood caused heavy flexing and wobble to the car that prevented a straight path. A redesign would feature four wheels with similar placement to the front wheels.

The Lever Arm angled to one side was a cause of the flex found in the back of the car. To counter this, a redesign would have the lever arm in the center to prevent over rotation.



DETAIL E
SCALE 1 : 2

The Variable Gear we designed could be resized to allow for smaller adjustments as the levels we set ended up having too much variation too the mechanical advantage of the car.

Title	REV
Reflection	1
Date: 5/12/23	SHEET 1 OF 1