RMIT University
School of Science and Technology (SST)
Group project semester B 2021

GRAVITY RACER DESIGN

Group: Under Defined

Students:

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I. Project Definition and Aim:

In this project, we will produce Cyber-truck 404 as ***Figure 1.1***. It will be made on a smaller scale compared with the soapbox car in the event, All-America Race. However, the function of our vehicle will be maintained as the soapbox car. To achieve fully the car's function, we must follow the given requirements for the derby:

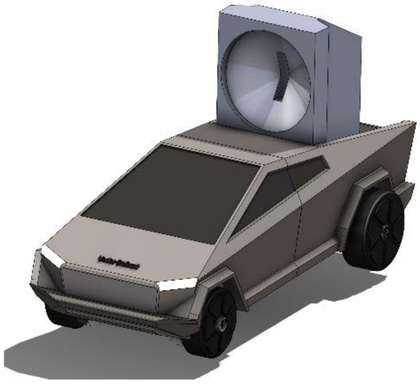


Figure 1.1: Isometric views of Cyber-truck 404 from Under-Defined.

- It must be capable of travelling more than 2 meters, totally, when running down the hill.
- It must be able to carry a 500-gram PASCO hooked mass, as a replacement of a down scale human and must not fall out the vehicle during the running.
- It must be able to withstand the collision with a 3mm thick acrylic wall at the end of the track to prove its durability.
- It needs characteristics that prove team's integrity by engraving the team's name on the surface, suitable with manufacturer condition (each part has maximum 13 x 13 x 13 cm dimension) and the derby only contains 12 parts.
- Cyber-truck 404's width must be less than the width of the PASCO Track.

In this project, we are required to provide a design report which is satisfied all descriptions such as Specific, Measurable, Achievable, Relevant, Time-based.

Sprint 1: Conceptual Design

It was from week 4 to week 5. Analyzing the project description to understand the scope and the requirement of the project. After examining the project description and produce ideal variables, we briefly produce a plan that satisfies the constraints:

- Wheels: estimating the radius and the weight of the wheels, because the rolling resistance is directly proportional to the Mass Moments of Inertia of the wheel $I_{CM} = \frac{1}{2} M \left(R_1^2 + R_2^2\right)$.
- Upper Body: its design should minimize the air resistance, hold the lower base and the cargo sturdily, and maintain the center of mass in an ideal position.
- Lower base: This part must be structured strong enough to support the entire weight of the vehicle and 500-gram mass and to prevent the car from damaging after the collision.
- Mass: The Centre of Mass ideally should be in the middle of the car and stay at near the track as possible, so this prevents the truck from collapsing over itself. The derby also must be heavy enough to not flip upside down after the collision.
- Bearing and rods: Research their information and find appropriate ones, and then reproduce them in Solidworks.

Sprint 2: Detailed Design

Start from the middle of week 6 to week 7, the second phase. At this stage, our team investigated the suitable dimensions of the truck. Moreover, all parts were listed and demonstrated below, the ***figure 2.1.***

Upper body:

The design of Tesla Cybertruck (**Appendix B**), [1] was borrowed to create a similar truck for this project. The body's width must be less than 85mm to run down the 100mm wide track. The body's volume must be fit to the given volume of the 3D printer. Hence, we separate the body into two separate parts as illustrated in **Appendix C** and **Appendix D**. The upper front body would be designed to minimize air resistance by making the front incline at a specific angle to reduce the frontal area, according to [2].

Cargo:

According to [3], a similar theory, the law of inertia. The cargo will be located at the rear of the car with 4 M3 screws bolted through the rear body down to the base to keep it in one solid piece to avoid a huge force that will destroy the whole truck. The mass has a hook and a cone-like shape on it so we took that design and engrave it to our cargo so the two will match up with large surface contact to withstand impact. In addition, the hook can only be pushed to the cargo through a rectangular shape path that we designed, then rotate the cargo 90 degrees to lock it with the cargo. Dimensions and pictures to illustrate that motion and locking system will be indicated in the Device Description and **Appendix A**, and **Appendix F**.

Bearing:

Bearings will be placed under the Bended base of the cart where it has purposedly designed to have 4 fit slots. The bearing type used in our car design is the 606 – RS [4]. Due to the limited access to purchase bearing, our bearings are provided by a member in our team. However, his bearings do not have rubber seal (RS stands for rubber seals), so we draw the bearing design on the Solidworks without rubber band but ensuring the closely matched up dimensions.

According Dat's sent image of his bearing, there are 7 balls per bearing and no rubber band as mentions (**Appendix H**). The bearing assembly can be found on [5].

Axletrees (rods):

There are 2 rods installed under the Bended base of this Cyber-truck 404. Those rods will be pierced through the hole of the inner rings of the bearings. The rods are made from acrylic as it is capable to withstand high surface resistance from the wheels and exterior impacts. Those 2 rods will have identical designs serving different purposes:

Back rod:

The back rod is used for the biggest pair of wheels. It has 5 triangle-shape alike slots as they fit the specialized Back Wheels. The trenches come along the rod body, as the rod rotates responding to the Big Wheels, the gaps on the body surface of the rod take advantage of air resistance which it gains more force to rotate. As the results, energy will be less dissipated while the cart travels at greater velocity. Therefore, the conversion from potential energy to kinetic energy is partly preserved (reducing heat loss, etc.).

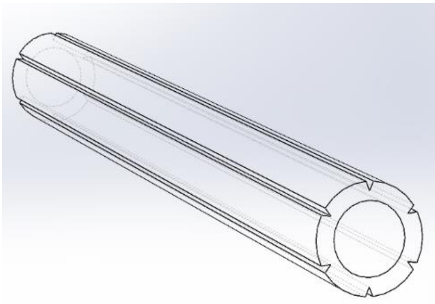


Figure 1.2: A conceptual design for the Back Rod of the Cyber-truck 404 in Solidworks platform

Front rod:

The front rod share some of the similarities in features as with the back rod. But the front rod does not have the trenches go along the rod, the trenches only limit at the mating areas between the Front Wheels and the rod. The smooth surface of the body in the middle also let the air pass through under the Bended base of the cart easily. On the other hand, the air resistance acting on the front rod is expected to be lowered (thesis).

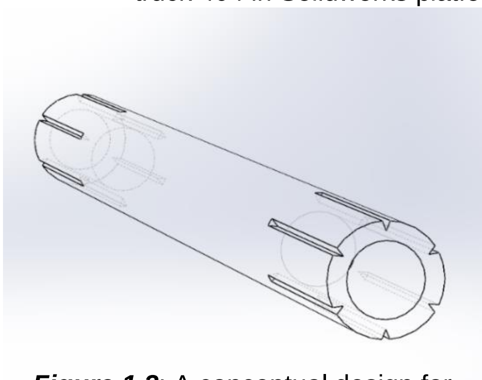


Figure 1.3: A conceptual design for the Front Rod of the Cyber-truck 404 in Solidworks platform

Wheels:

The Cyber-truck 404 runs with 2 pairs of wheels which are back wheels and front wheels. Two pairs of wheels have the same design to make a synchronization in the truck. The back wheels, however, were designed with a larger diameter compared with the front ones. By doing this, our truck would not be parallel to the contacted surface, it would be inclined forward. This would create a benefit when the car moving on the slope because the larger acceleration would be generated. Lastly, to increase the friction between the wheels and the surface, it will be constructed with flexible resin.

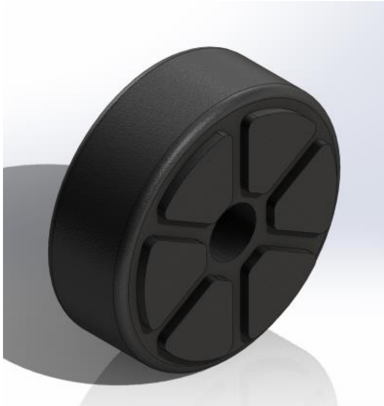


Figure 1.4: Design of Cyber-truck 404's wheel.

Base:

The base was made from a clear 5mm acrylic sheet since its dimensions were not complex. Laser-cut parts are faster to make with high precision. Four holes' diameter on the base were dimensioned as close as the bearing size to fit in nicely. Then, we would apply heat bending to the 5mm base to make those holes parallel with each other then we could slide rods through. To bend the acrylic, we use a custom 8mm heat line stove to heat the sheet, the stove will ensure only 8mm line will be heating up to bend for precision. When we bend the acrylic sheet 90 degrees it will have 2 fillets being created, the inner and the outer fillet. Depend on the thickness of the acrylic the fillet will be different. For instance, a 5mm acrylic sheet will have a 5mm outer and 2.5mm inner fillet, respectively.

Sprint 3: Manufacturing

Tough resin, flexible resin and acrylic were three main materials. There were many reasons and aims behind them. Firstly, we choose resin because it can be 3D printed with complex dimensional parts and a variety of resin types that meet our design specs. For instance, the body of the vehicle will be printed with tough resin to have the ability to withstand the impact. Secondly, we maximize the friction between the wheel and the track so that all the rotation forces of the wheels can be delivered to the track, to minimize and prevent the car from slipping, and losing its direction. So, flexible resin was used to satisfy the spec. The wheels, however, were made completely out of Flexible Resin, it can lose its cylinder shape for the rolling motion because more than 500g of mass is acting on it, so the wheel must be one solid shape with 100% infill, except holes for the axles. Thirdly we chose acrylic because it can be laser cut with very high accuracy, the base will have four holes for bearings, and we will also bend it after cutting.

Sprint 4: Testing

Down Slope

For this section, the car must go down the incline track (5 to 30 degrees) in a straight line without falling. So, we have flexible wheels so that all of them can roll equally to each other and stick on the track. Depending on the angle of the slope, the car would gain a greater or smaller speed, as the larger the angle the faster will the car accelerate. So, the flexible wheels will also prevent the slid effect and keep the maximum energy for the next horizontal drag.

Horizontal free drag

The energy that the car gains from the incline slope will be decreased when the downforce of the car impact the floor. The inertia must be care since the hooked mass travelled downslope with the car, but the mass is weight more than the car so the mass will have larger inertia than the car, also according to [3]. Because of this, there would be two scenarios that could happen. Firstly, if the car was not bonded well with the mass, they will be separated and crashed by the differences of the inertia force being applied on them. Secondly, if the mass and the car were well bonded, the inertial force of the mass will transfer to the car and make the car travel further. So, the second scenario is one of the aims in our design to make sure it happened.

Collision

Referencing [3], the car hit the 3mm thickness acrylic the car will stop its motion and bounce back, the car loses all its inertia, however, the mass isn't. The car hit the wall will create counterforce between them. If the car's parts were well bonded together, they could withstand all the impacts and bounce back as a solid object, and vice versa. Because, the counterforce of the wall will be larger than the car, but the force is equally distributed in the car. So, we make all the parts bond well together with huge surface contact so that the force create by the crash can distribute through all the cars, and then one peace could have remained.

Durability

To increase its strength, we examined vehicle's area where would be impacted the most when colliding with the wall. We pointed out three areas, for instance, vehicle's front and back face, and its tank. After analyzing the most impacted areas, we started to reconstruct the inner designs of the upper body by adding more thickness and components. **Appendix E** below will show clearer views of these upgrades.

II. Design Mechanism and Calculations:

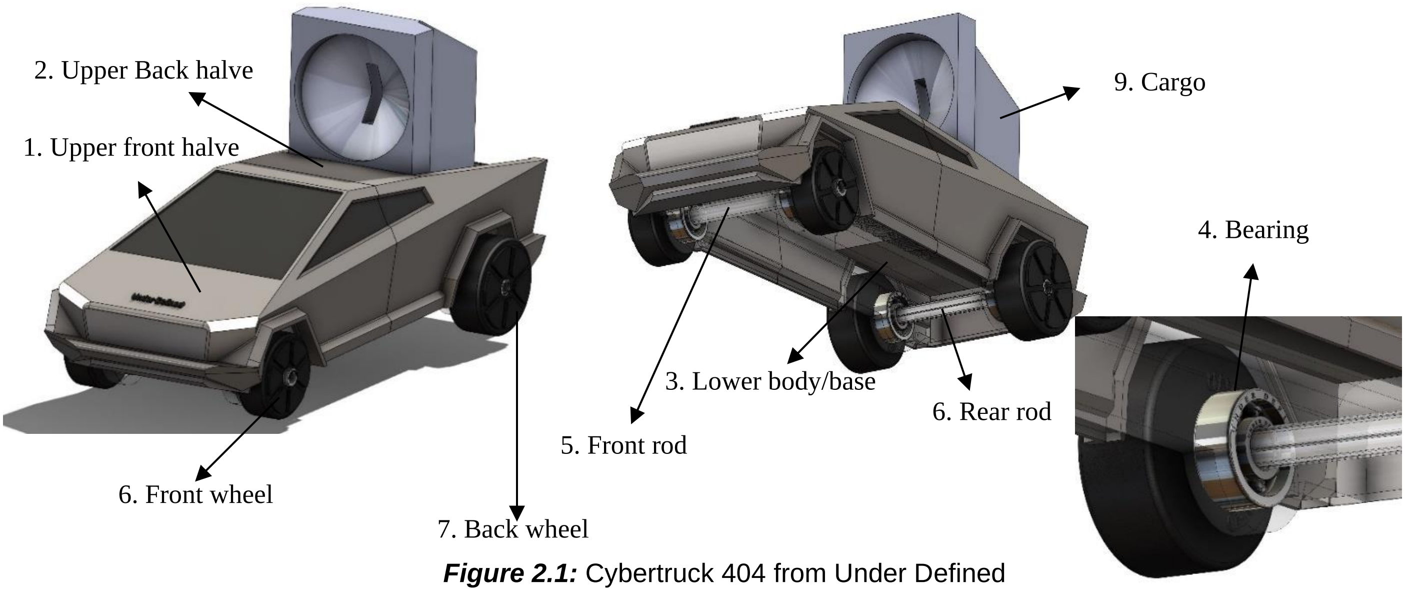


Figure 2.1: Cybertruck 404 from Under Defined

Calculation

Our team must consider, examine, and hypothesis all diverse imperfect circumstances, including air resistance, friction force of wheels and Pasco Track's surface, Mass Moments of Inertia of rotating wheels, and the law of conservation of energy of the whole system. Therefore, we can produce results that are very similar to real measurements. Calculating the theoretical maximum speed of our Cyber-truck, some physic formula will be called:

Gravitational force [6]**:**

$$|\vec{F}| = Mgsin\theta$$

Drag force [8]**:**

$$|\overrightarrow{F_D}| = C_d \frac{pv^2}{2} A$$

Moment of inertia (for hollow cylinder) [7]**:**

$$I = \frac{1}{2} m({R_1}^2 + {R_2}^2)$$

Conservation of energy [9]**:**

$$PE_i = KE_f$$

$$\Rightarrow PE_i = KE_{trans} + KE_{rot}$$

$$\Rightarrow Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$$

And other circular motion formulas [10]

Where:

$|\vec{F}|$ = the magnitude of the gravitational force acting on the car (N)

M = mass of the car (kg)

g = the gravitational acceleration constant on Earth, equal to 9.81m/s^2

θ = the angle of the slope, measured from the horizontal, ranging from 5 to 30 degrees

I = the mass moment of inertia of the hollow cylinder around the perpendicular axis of rotation, ($kg.m^2$)

m = mass of a wheel (kg)

R_1 = the inner radius of the wheel (m)

R_2 = the outer radius of the wheel (m)

$|\vec{F_D}|$ = the magnitude of the Drag Force acting on the Gravity Racer (N)

C_d = the drag coefficient is a dimensionless experimental aerodynamics value

ρ = the density of air on Earth, 1.225 $kg/m3$

v = the speed of the car, m/s.

A = the frontal area of the car, m^2

PE_i = Potential energy (initial) (J)

KE_{trans} = translational kinetic energy (J)

KE_{rot} = rotational kinetic energy (J)

Besides, due to lack of experiment with real models, there are some assumptions that should be noticed:

- The calculations below are made based on the given information. Therefore they do not reflect the performance of the actual car. However, they are used to improve the efficiency of the vehicle.
- The total mass of the car includes a 500g Pasco hooked mass.
- The force that alters the vehicle's motion at the end of the slope before the vehicle moves sideways will also be neglected for easier calculations.
- For basic calculation, each wheel carries a quarter of the car's mass. Furthermore, in case the front wheels and back wheels have a slightly different radius**, the average value will be used for all wheels.**
- The drag coefficient is approximately calculated using Solidworks Simulation (**Appendix G)** [11].

Our implementation method

By using conservation of energy, we can find the maximum velocity that our car should achieve. As the car is released on an inclined track, its potential energy goes to translational kinetic energy (of the car), rotational kinetic energy (of the wheels), and work done by friction force (F_{fr}) and drag force (F_D):

$$\Delta PE = \Delta KE + \left(F_{fr} + F_D\right).d$$

The friction force is negligible because the coefficient of rolling resistance is very small [9], and its exact value is unavailable. Thus:

$$\Delta PE = \Delta KE + F_D.d$$

$$\Rightarrow PE_i = KE_{trans} + KE_{rot} + F_D.d$$

$$\Rightarrow Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 + F_D.d$$

As the wheels are rolling, we can substitute the relationship $\omega = \frac{v}{R}$ [10] into the expression, following:

$$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}\left[\frac{1}{2}m({R_1}^2 + {R_2}^2)\right]\left(\frac{v^2}{{R_2}^2}\right) + F_D.d$$

$$\Rightarrow\ Mgh = \frac{1}{2}Mv^2 + \frac{1}{4}m\left(\frac{{R_1}^2 + {R_2}^2}{{R_2}^2}\right)v^2 + F_D.d$$

$$\Rightarrow\ Mgh = v^2\left[\frac{1}{2}M + \frac{1}{4}m\left(\frac{{R_1}^2}{{R_2}^2} + 1\right)\right] + F_D.d$$

Substitute $h = dsin\theta$, we can have the equation for the final velocity:

$$v = \sqrt{\frac{Mgdsin\theta - F_D.d}{\frac{1}{2}M + \frac{1}{4}m\left(\frac{{R_1}^2}{{R_2}^2} + 1\right)}}$$

Where:

M = the mass of the car (kg)

m = the mass of 4 wheels (kg)

R_1 = the inner radius of the wheel (m)

R_2 = the outer radius of the wheel (m)

d = the distance the car runs on the inclined track

In this expression, the drag force will be calculated as the average value, since it is proportional to the square of the speed, which is hard to identify. To get the average value of drag force, first, we will find the final velocity of the car running on the slope of 30 degrees in ideal conditions (without drag force), using:

$$v = \sqrt{\frac{Mgdsin\theta}{\frac{1}{2}M + \frac{1}{4}m\left(\frac{{R_1}^2}{{R_2}^2} + 1\right)}} = \sqrt{\frac{0.822 \times 9.8 \times 1 \times sin30°}{\frac{1}{2}0.822 + \frac{1}{4}0.039\left(\frac{0.003^2}{0.016^2} + 1\right)}} = 3.092\ (m/s)$$

Now, the mean value of F_D on [0,3.092] (from $v = 0\ m/s$ to $v = 3.092\ m/s$) is defined by:

$$\overline{F_D} = \frac{1}{3.092 - 0}\int_0^{3.092}(C_d\frac{pv^2}{2}A)\ dv\ \ [13]$$

$$= \frac{C_d pA}{3.092 \times 2}\left[\frac{v^3}{3}\right]_0^{3.092} = \frac{0.86 \times 1.225 \times 0.0055}{3.092 \times 2 \times 3}(3.092^3) = 0.0092\ (N)$$

We put this drag force magnitude into the expression of terminal velocity:

$$v = \sqrt{\frac{Mgdsin\theta - F_D.d}{\frac{1}{2}M + \frac{1}{4}m\left(\frac{{R_1}^2}{{R_2}^2} + 1\right)}} = \sqrt{\frac{0.822 \times 9.8 \times 1 \times sin30° - 0.0092 \times 1}{\frac{1}{2}0.822 + \frac{1}{4}0.039\left(\frac{0.003^2}{0.016^2} + 1\right)}} = 3.089\ (m/s)$$

Below is the results of terminal velocity due to different slope's angle:

***Table 2.1**: Maximum velocity in different slopes*

Total mass M (kg)	Four wheels mass m (kg)	Inner raidus R_1 (m)	Outer radius R_2 (m)	Distance d (m)
0.822	0.039	0.003	0.016	1

Angle (degree)	5	10	15	20	25	30
Velocity (m/s)	1.283	1.817	2.220	2.554	2.84	3.089

Our goals:

The total mass of the car:

As the equation for final velocity above, the M (total mass) contributes a small part to the velocity. This is understandable because although higher mass leads to a larger force pulling the car down the slope, it also causes more friction force on the wheel. However, if we want more speed down the slope, we should increase the total mass.

Wheel's radius:

The analysis above shows that when the car runs down the slope, its initial energy is divided mainly to translational kinetic energy ($\frac{1}{2}Mv^2$) and rotational kinetic energy ($\frac{1}{2}I\omega^2$) if we assume drag force is small. The lower moment of inertia I is, the more energy goes into translation [9]. Thus, the car moves faster. The moment of inertia is dependent on the mass and the radius of the wheel. If the wheel is heavy and has its mass far away from the center, its moment of inertia increases.

About the moment of inertia of a wheel, the higher the magnitude is, the harder for the wheel to accelerate or decelerate. In this project, our team aims to design a car that can run fast after going out of the slope. Therefore, the ideal wheel will have a small value of the moment of inertia (I) but still large enough to prevent the car from stopping when changing the direction suddenly.

Frontal area:

This characteristic is important to all motion objects which want a high-speed movement. The frontal area, together with the drag coefficient (C_d), velocity, and density of air, contributes to the drag force, which lowers the car's speed, by the expression:

$$\left|\overrightarrow{F_D}\right| = C_d \frac{pv^2}{2} A \ (N)$$

Therefore, the car needs to be in a shape that lowers the drag coefficient and the frontal area as much as possible. Additionally, the car must be strong enough and have enough space for a 500g Pasco hooked mass.

Key variables

Table 2.2: *Table of ideal variables that we will strive for in our design*

Variable	Ideal condition	Design description	Achievability
Body	Stay in form after collision	Increase the thickness appropriately, implementing others structure inside the body.	Achieved
	Minimize air resistance	Utilize modern design to produce good airflow and widen contact area for force distribution	Unachieved
Rod	Creating a consistent rotation motion with the wheel. Increase rotation force due to air resistance	Back rod has 5 triangle-alike trenches fitting with the spikes from the Back Wheel.	Unachieved
Wheel	Minimize rolling resistance Maximize traction with the track Uniform in motion	The wheels have smooth surface in order to keep a wide area in contact with the track's surface to prevent sliding. The wheels and rods system keeps right and left side of the car moving at the same pace, prevents sudden change in unwanted direction.	Achieved
Cargo	Be able to keep the PASCO weight to the end of the test	The cargo system will lock the weight on the car back and hold it in place.	Achieved
Durability	The car has no visible damage, all parts stay connected and the car stay functional after the test	With force contribution design from the front part of the car and binding system between parts, the car will have a great possibility to survive the test	Achieved

III. Device Description:

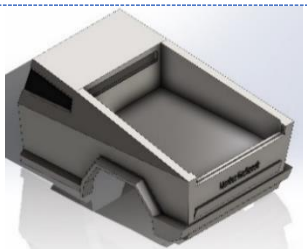
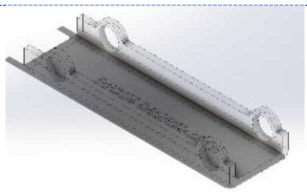
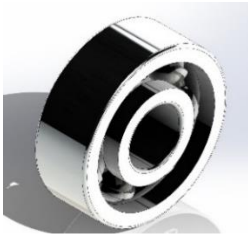
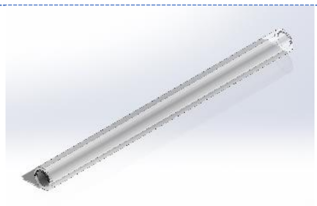
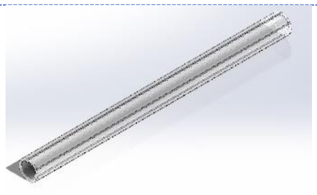
Bill of material:

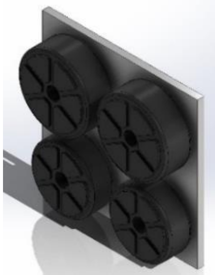
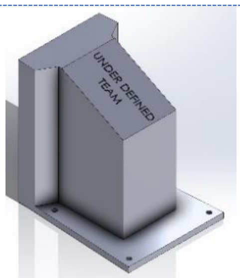
Table 3.1: *Bill of all parts of our design*

Component	Material	Density(g/mm^3)	Volume(mm^3)	Weight (g) per quantity	Quantity
Upper front	Tough Resin	0.00111	22054.35	24.48	1
Upper back			42818.25	47.52	1
Cargo			99290.87	110.21	1
Bearing	Chrome Stainless Steel	0.0078	731.56	5.70	4
Front Wheel	Flexible Resin	0.00115 [12]	6632.12	7.62	2
Back Wheel			10332.91	11.88	2
Base	Acrylic	0.00119	62471.26	74.96	1
Front Rod			1241.21	1.48	1
Back Rod			1190.96	1.42	1
	Total		**274292.27**	**321.87**	**14**

List of components

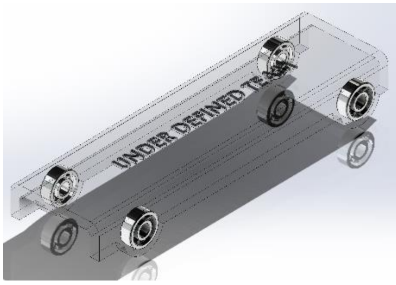
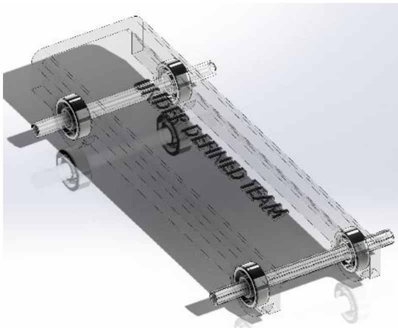
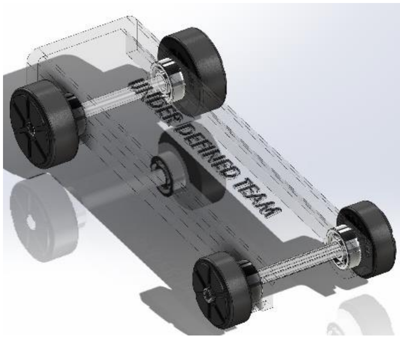
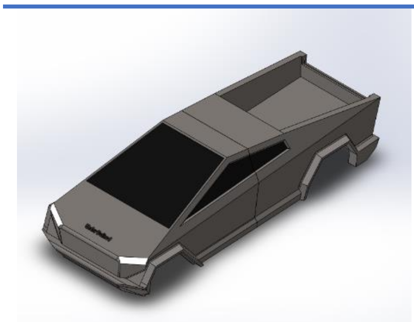
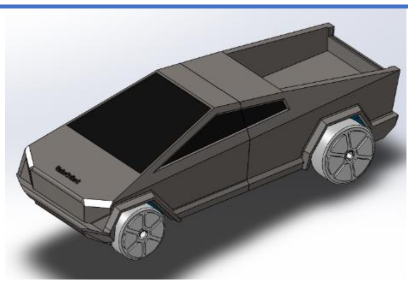
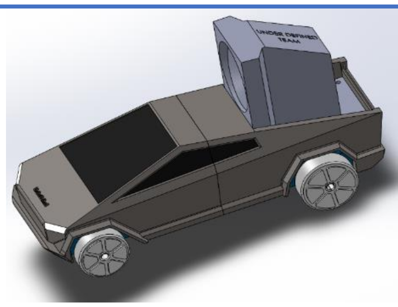
Table 3.2: *List of components*

	Name	3D Module	Quantity	Material, Manufacturing process	Dimensions (mm)	Primary feature
1	Upper front halve		1	Tough resin 3D Printer	99.82 x 82.57 x 50.6	Decorating and Increasing the durability
2	Upper back halve		1	Tough Resin 3D Printer	97.41 x 72.07 x 49.12	Decorating and Increasing the durability and hold the cargo.
3	Base		1	Acrylic Laser cutter	174.5 x 50 x 27	Support and secure the upper body. Hold other below parts.
4	Bearing		4	There is no manufacturing for these bearing.	Φ17 x 6	The balls reduce the friction and allow the wheels-rods to rotate smoothly.
5	Front rod		1	Acrylic Available on the market	Φ6 x 79	Rotating the wheel. Securing and holding the front wheels near to base and bearing.
6	Rear rod		1	Acrylic Available on the market	Φ6 x 79	Rotating the wheel. Securing and holding the rear wheels near to base and bearing.

7, 8	Front and Rear wheels in a part file		1 (2 front and 2 rear wheels)	Flexible Resin 3D printer	72 x 17 x 68	All wheels must be rotating.
9	Cargo/mass holder		1	Tough Resin 3D printer	66.85 x 54.03 x 70	Hold and secure the cargo.

Assemble Guide

Table 3.3: *Assemble guide*

 **Step 1**: Place 4 bearings into the base	 **Step 2**: Insert front rod and back rod through the bearings	 **Step 3**: Insert 4 wheels into the rods
 **Step 4**: Bind two halves of the upper body	 **Step 5**: Bind Upper body with the base system	 **Step 6**: Place the cargo in the trunk and keep it fixed using 4 screws

IV. References:

[1] *Tesla: Cybertruck*. Accessed on: Aug. 6, 2021. [Online]. Available: https://www.tesla.com/cybertruck

[2] Bailey, K. "How Can Understanding Physics Help me go Faster on My Bike." *Let's Talk Science*, Jul.23, 2019. Accessed on: Aug. 5, 2021. [Online]. Available: https://letstalkscience.ca/educational-resources/stem-in-context/how-can-understanding-physics-help-me-go-faster-on-my-bike

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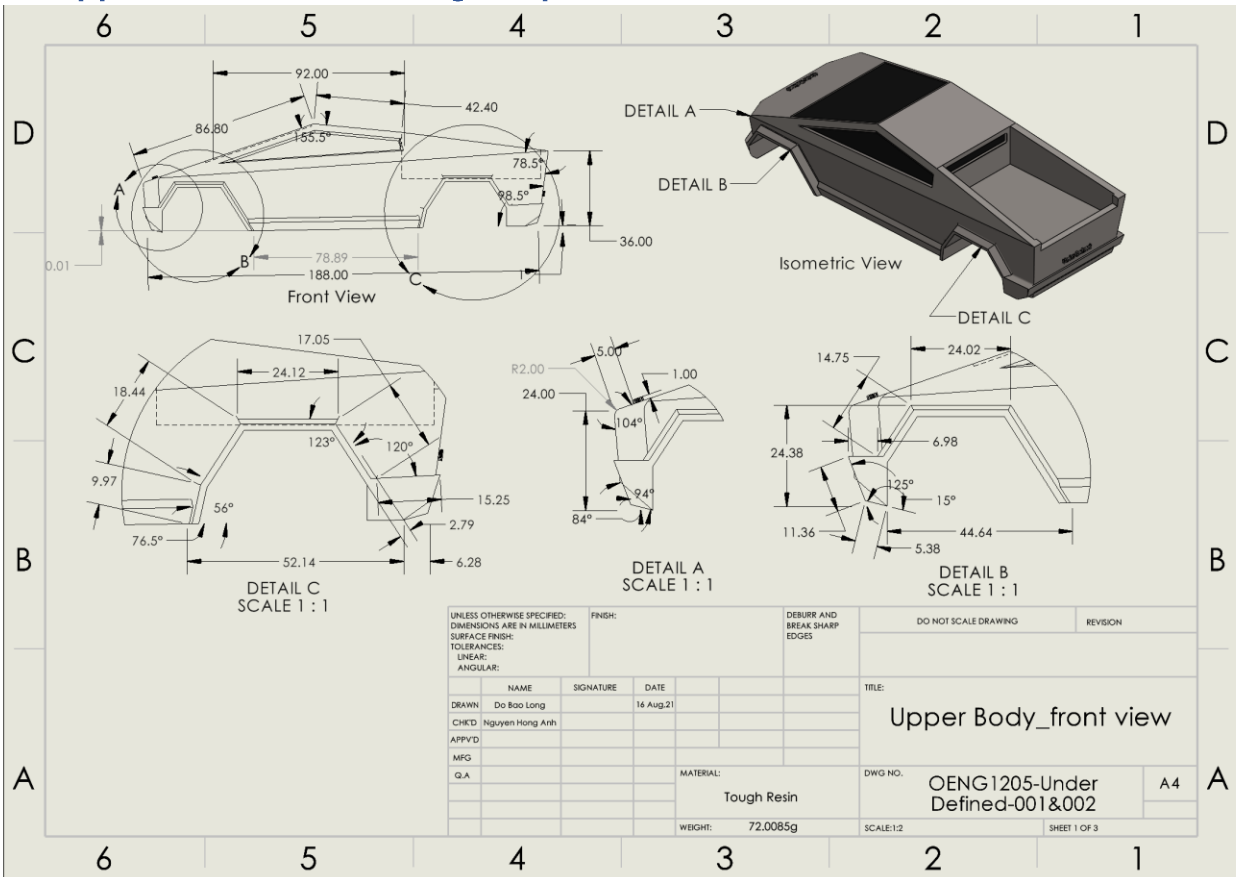
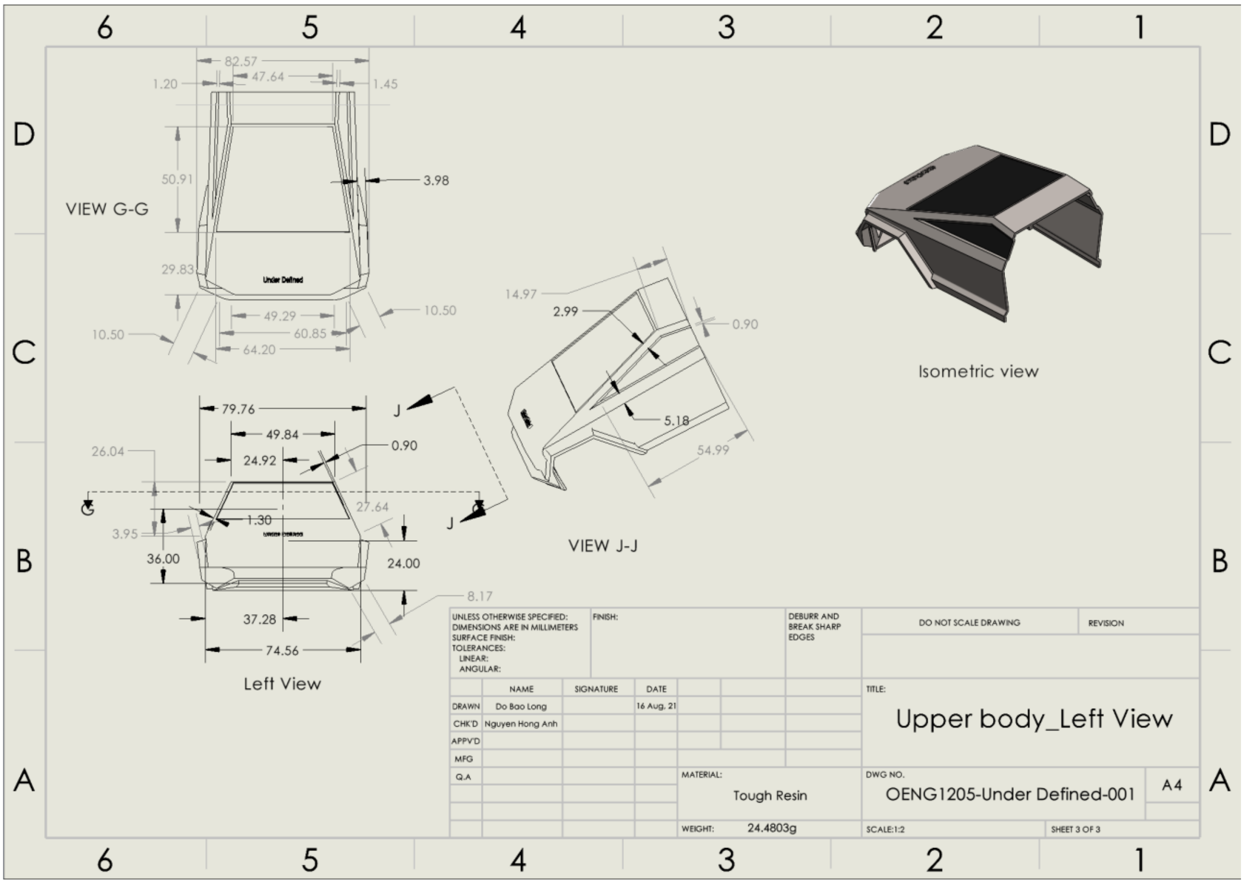
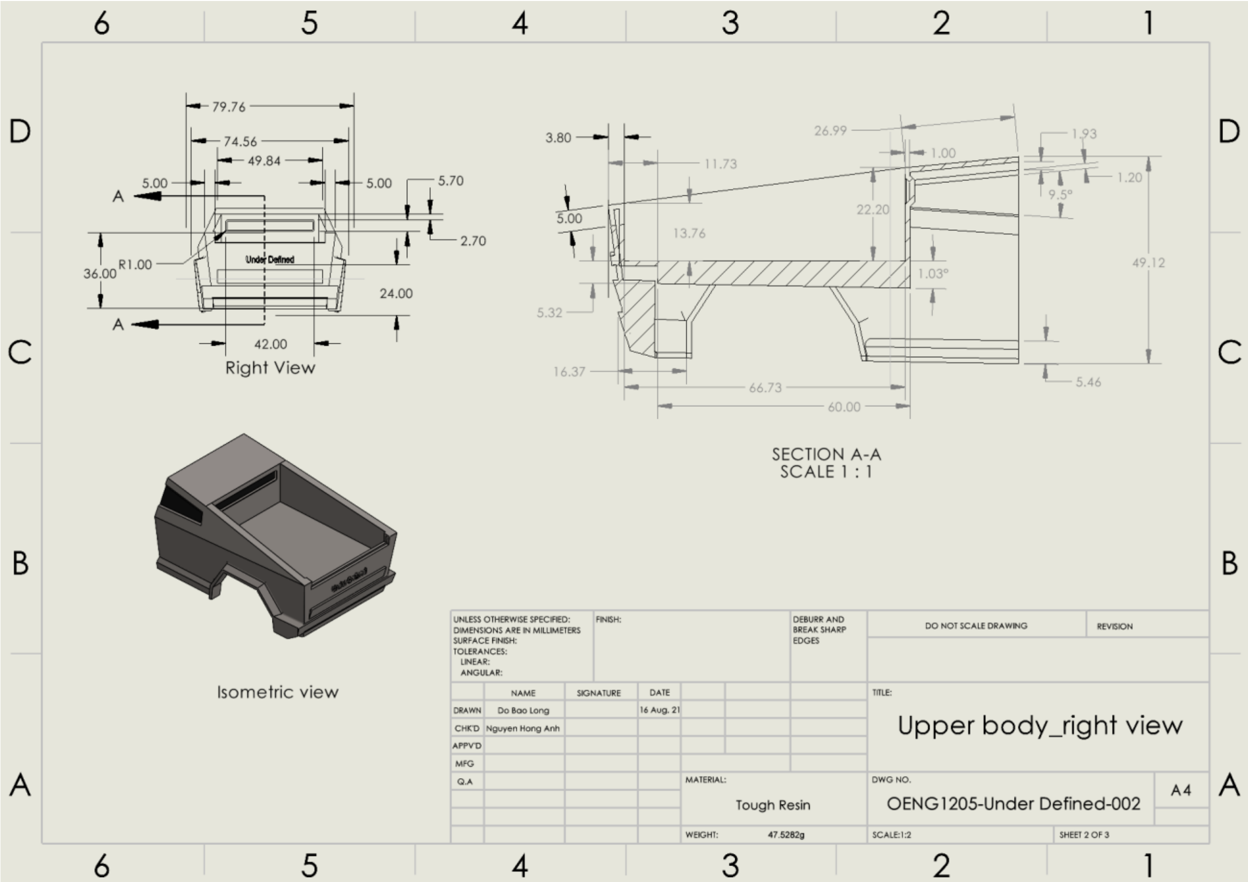
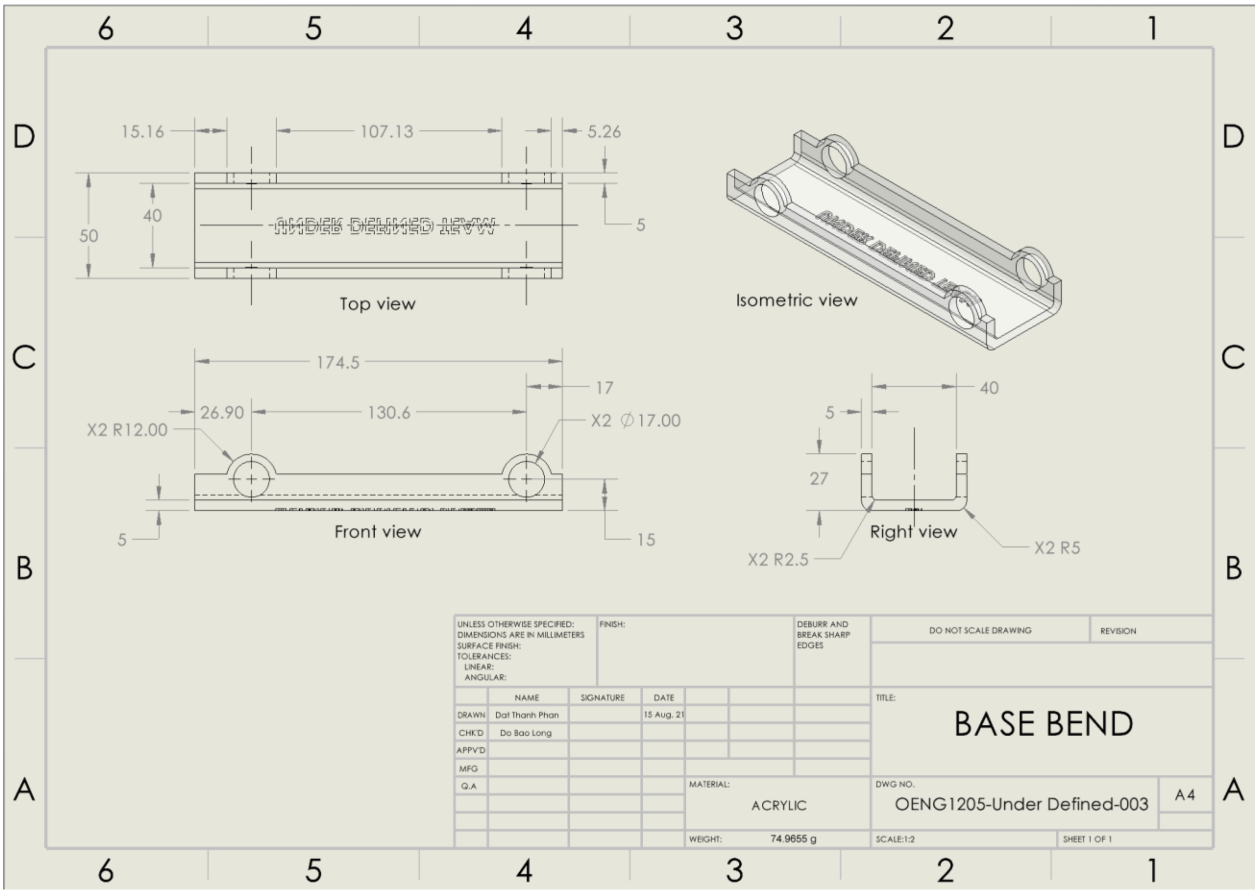
V. Appendices:

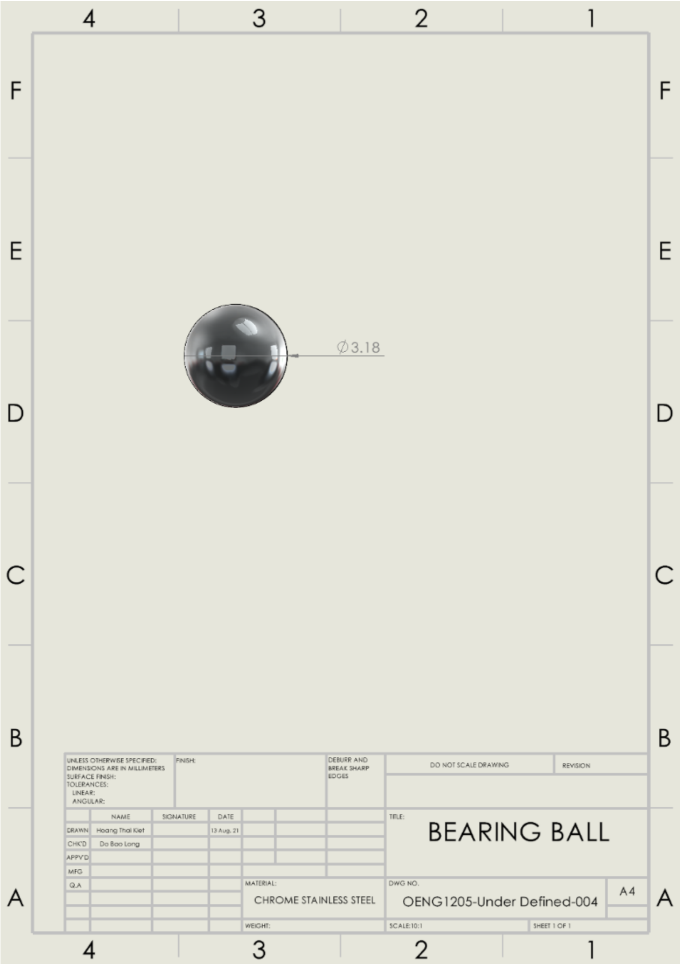
Appendix A – All drawings of parts

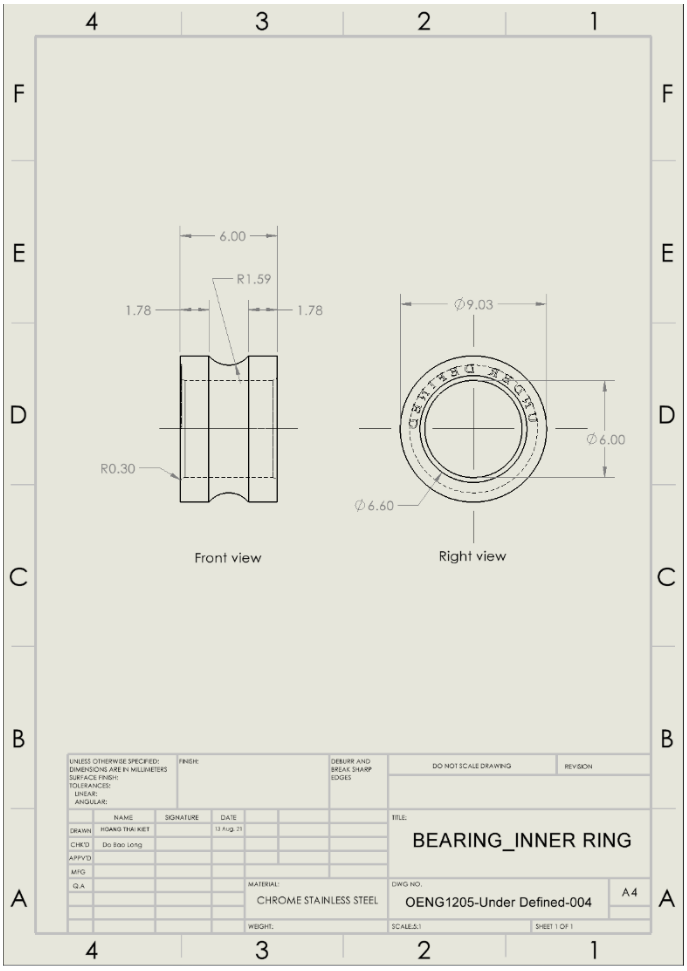


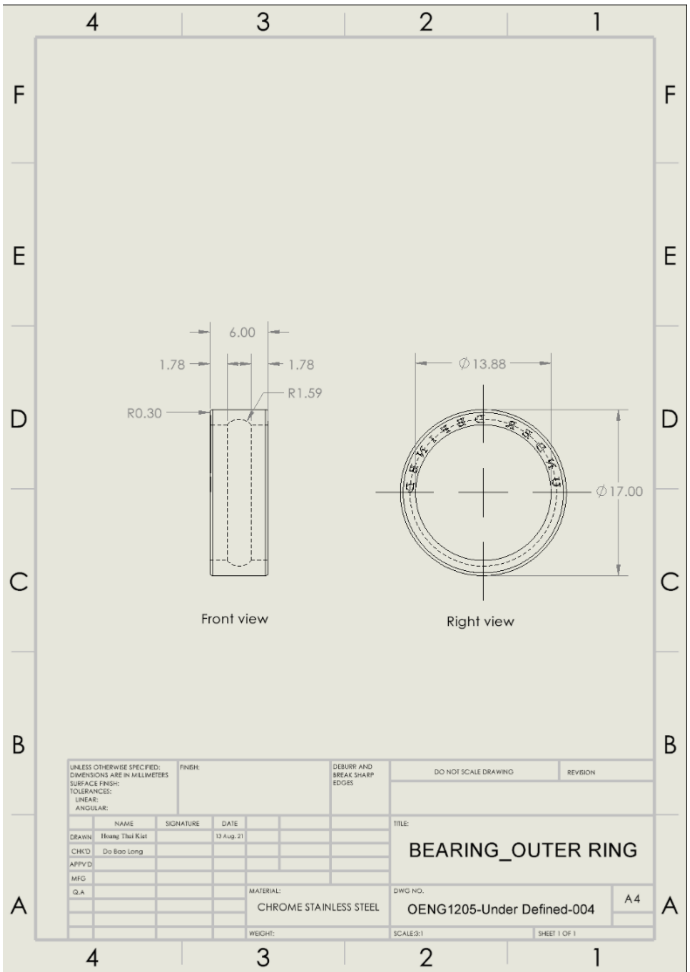


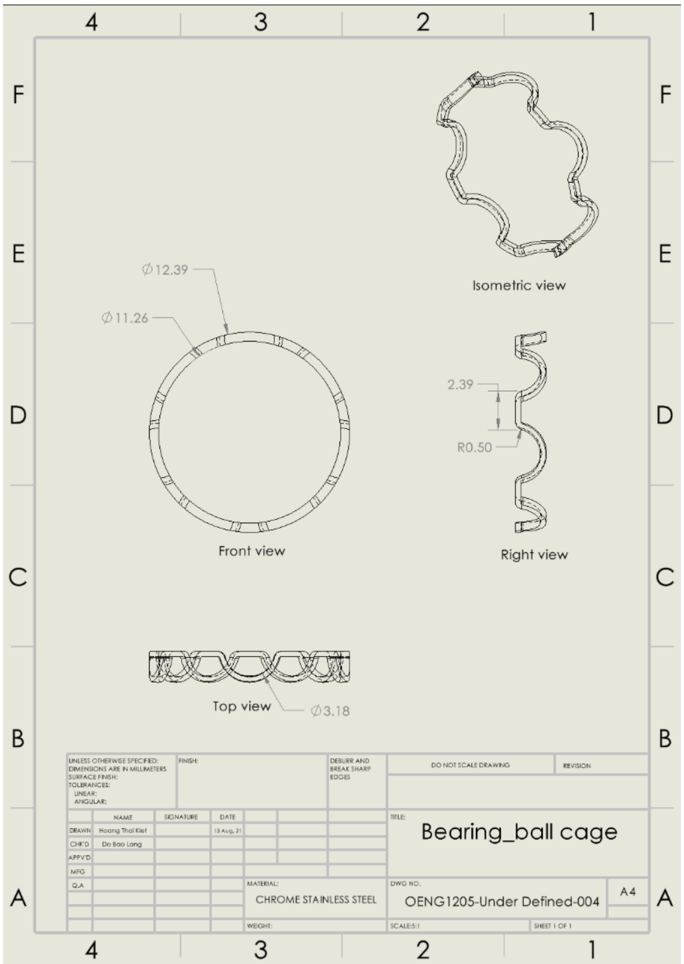

Right View
SECTION A-A
SCALE 1 : 1
Isometric view
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Do Bao Long
16 Aug. 21
CHK'D
Nguyen Hong Anh
APPV'D
MFG
Q.A
MATERIAL:
Tough Resin
WEIGHT:
47.5282g
TITLE:
Upper body_right view
DWG NO.
OENG1205-Under Defined-002
A4
SCALE:1:2
SHEET 2 OF 3

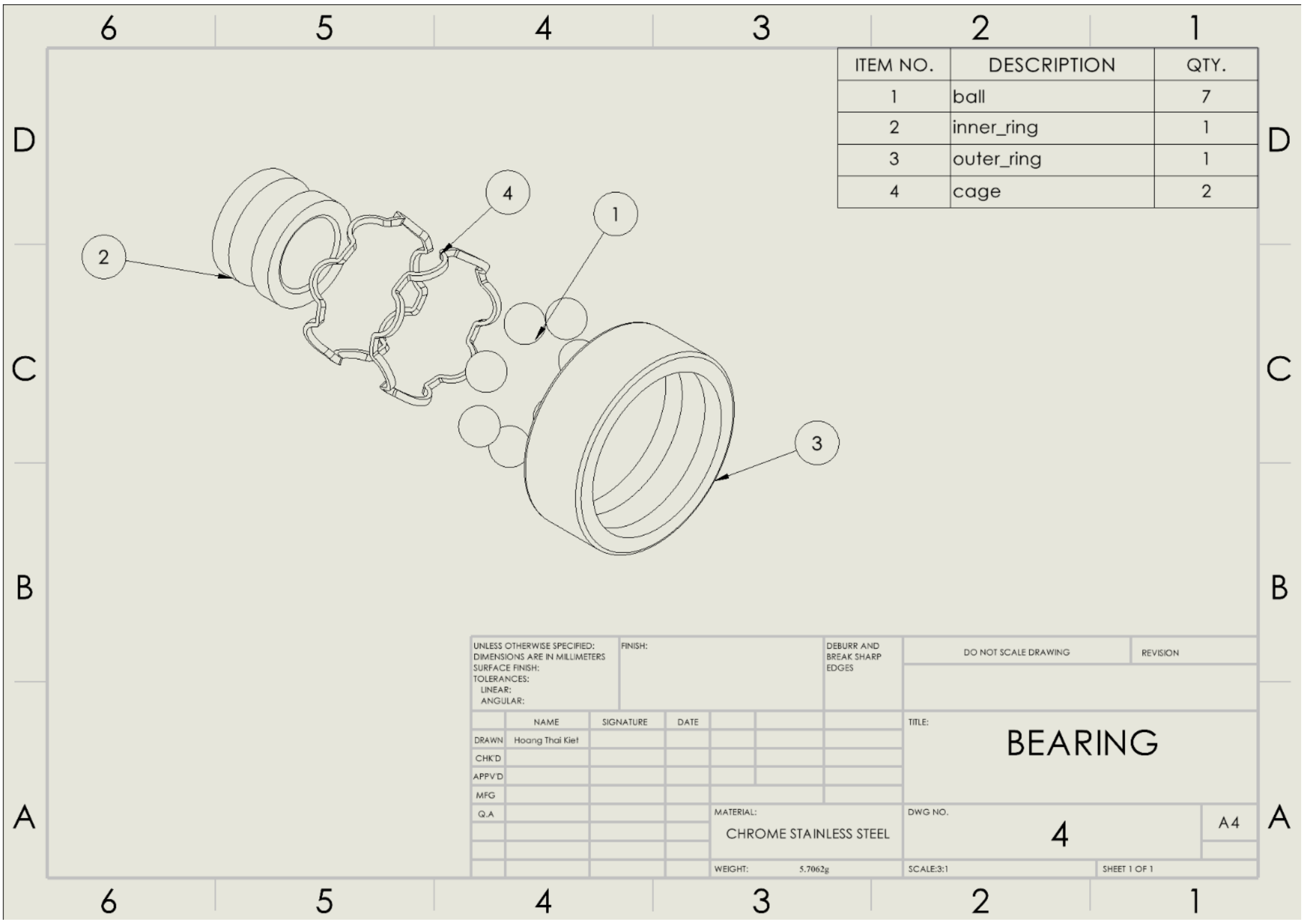

Top view
Isometric view
Front view
Right view
X2 R12.00
X2 Ø17.00
X2 R2.5
X2 R5
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Dat Thanh Phan
15 Aug. 21
CHK'D
Do Bao Long
APPV'D
MFG
Q.A
MATERIAL:
ACRYLIC
WEIGHT:
74.9655 g
TITLE:
BASE BEND
DWG NO.
OENG1205-Under Defined-003
A4
SCALE:1:2
SHEET 1 OF 1


Ø3.18
BEARING BALL
CHROME STAINLESS STEEL
OENG1205-Under Defined-004
A4
DO NOT SCALE DRAWING
Hoang Thai Kiet
Do Bao Long
13 Aug. 21

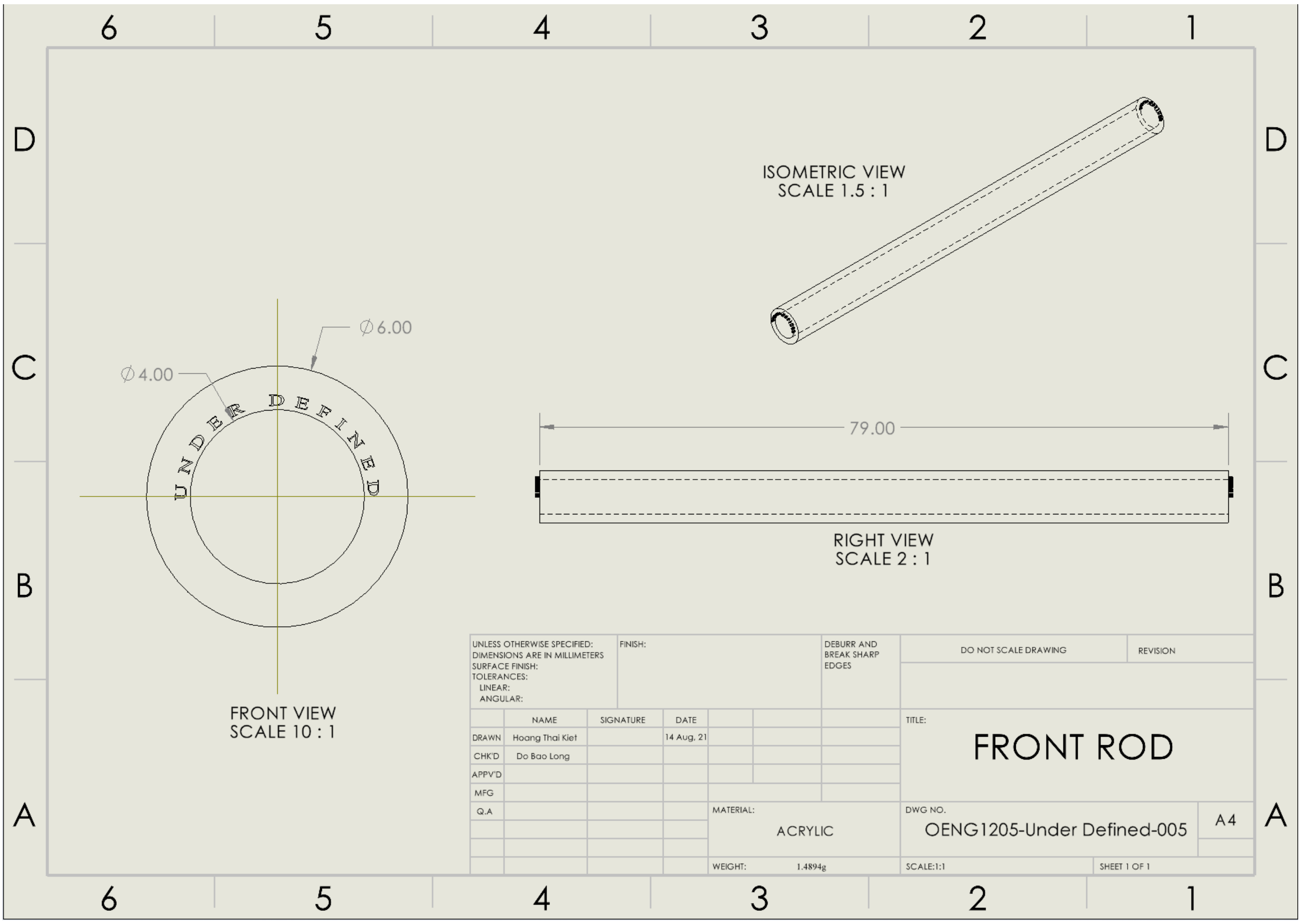

6.00
R1.59
1.78
1.78
Ø9.03
Ø6.00
R0.30
Ø6.60
Front view
Right view
BEARING_INNER RING
CHROME STAINLESS STEEL
OENG1205-Under Defined-004
A4

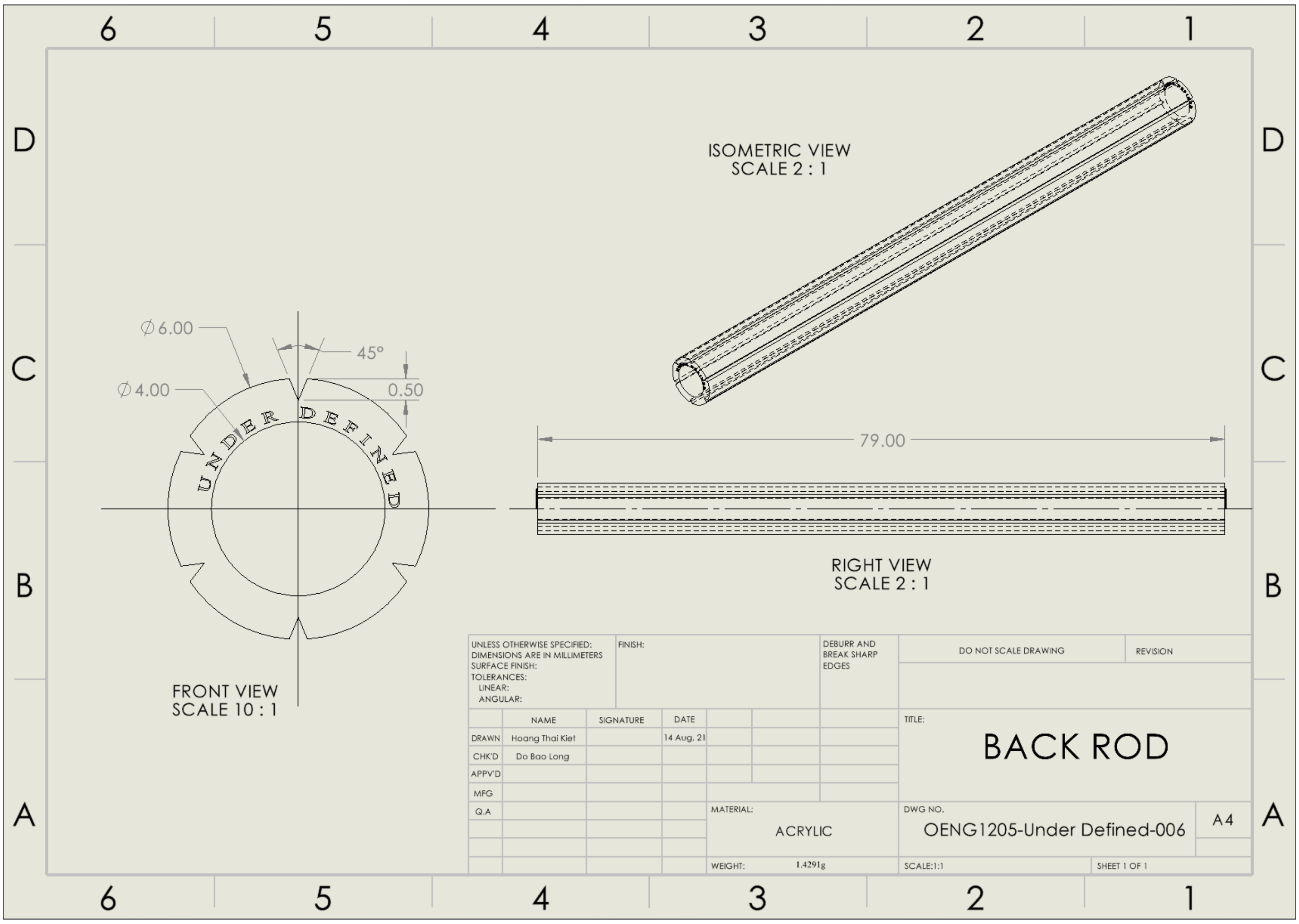

6.00
1.78
1.78
R1.59
R0.30
Ø13.88
Ø17.00
Front view
Right view
BEARING_OUTER RING
CHROME STAINLESS STEEL
OENG1205-Under Defined-004
A4

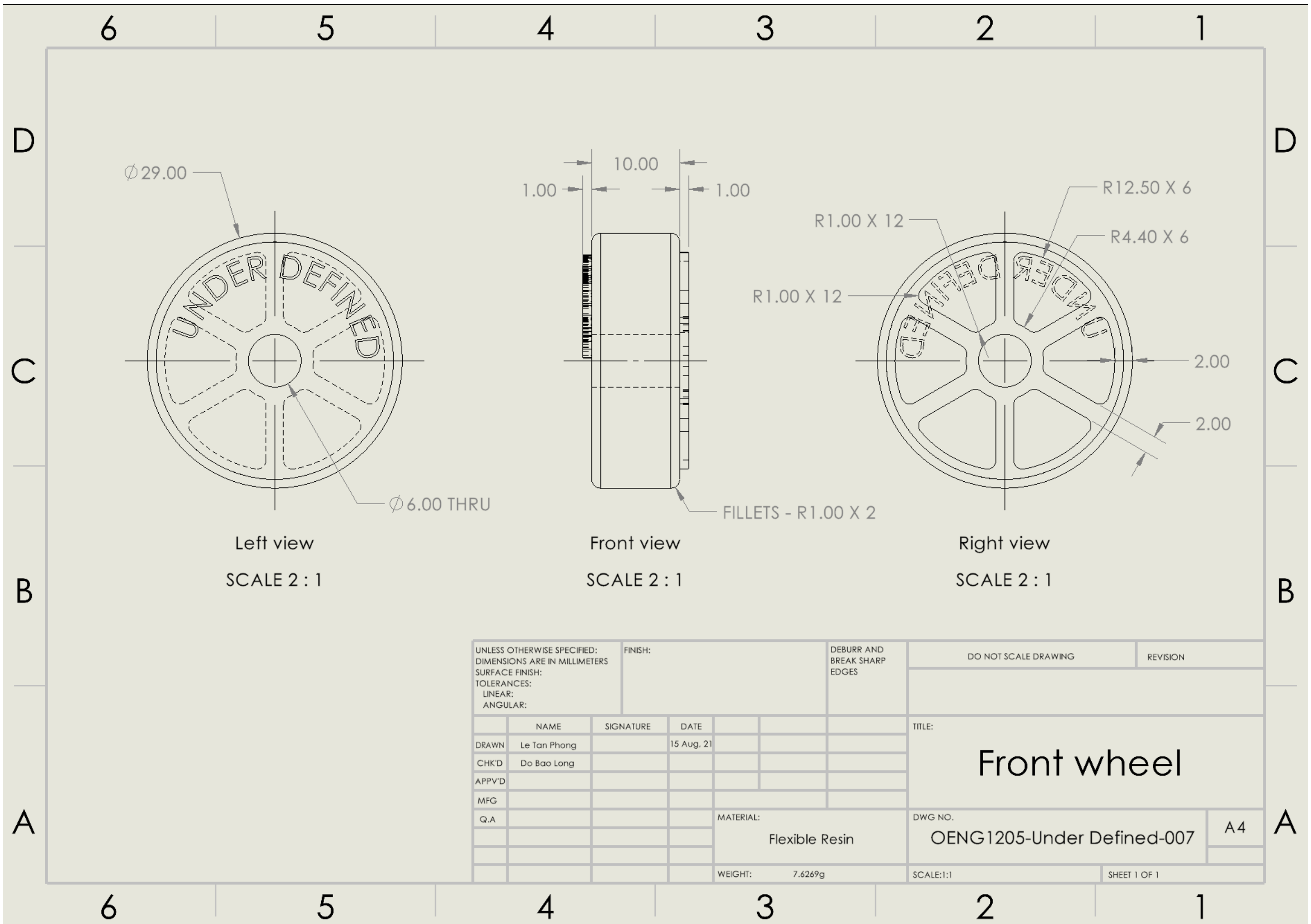

Isometric view
Ø12.39
Ø11.26
2.39
R0.50
Front view
Right view
Top view
Ø3.18
Bearing_ball cage
CHROME STAINLESS STEEL
OENG1205-Under Defined-004
A4

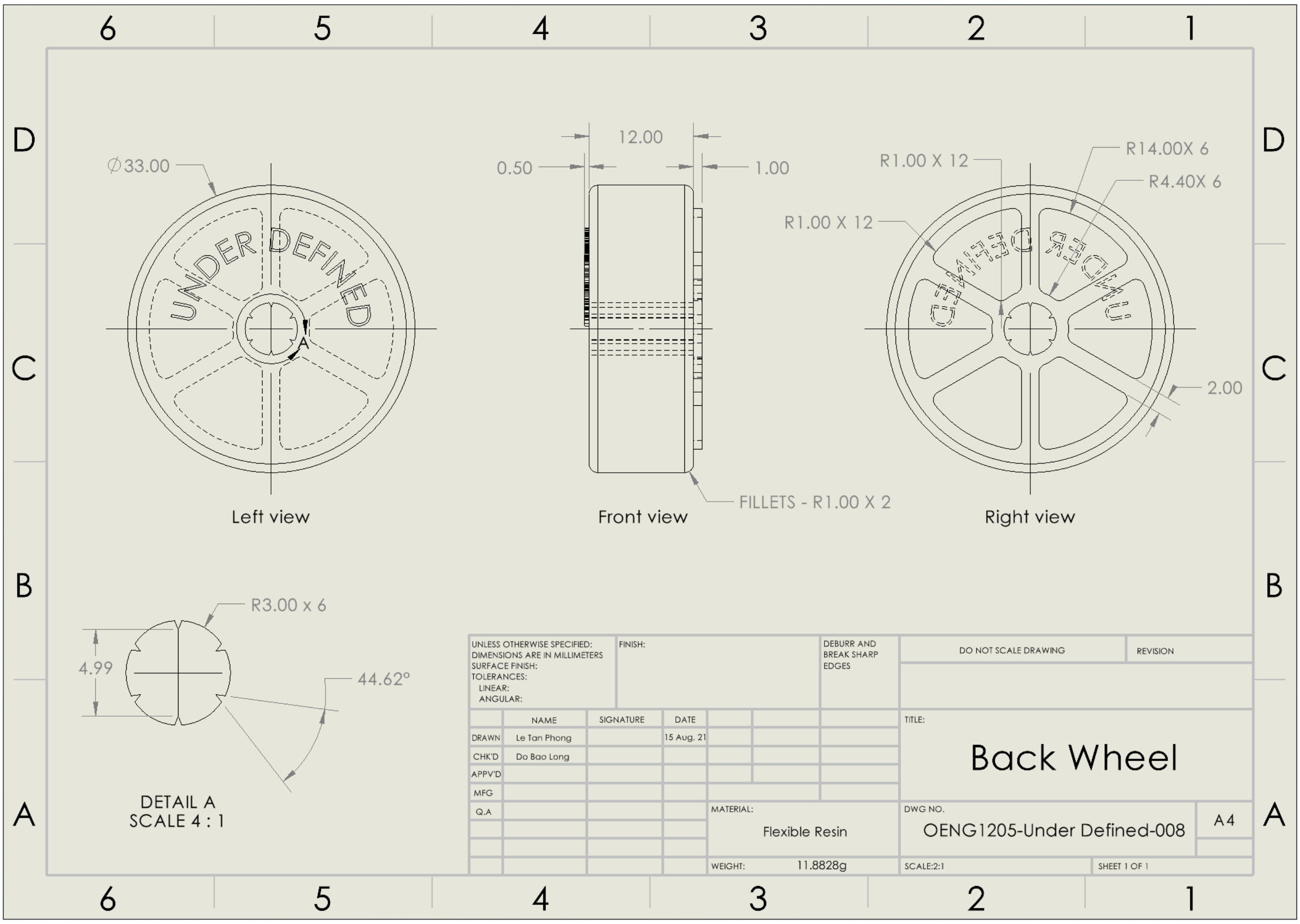


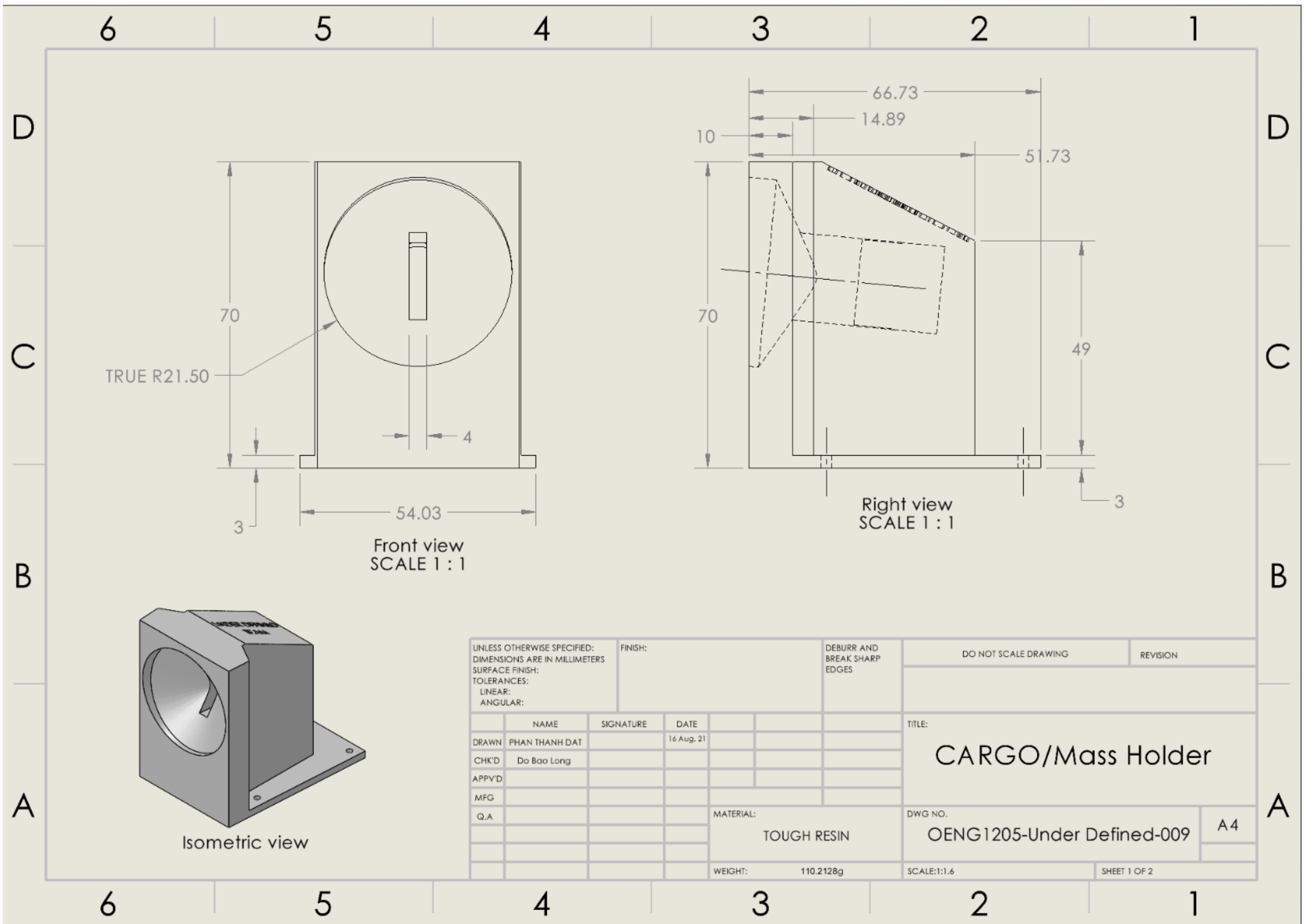
ITEM NO.	DESCRIPTION	QTY.
1	ball	7
2	inner_ring	1
3	outer_ring	1
4	cage	2

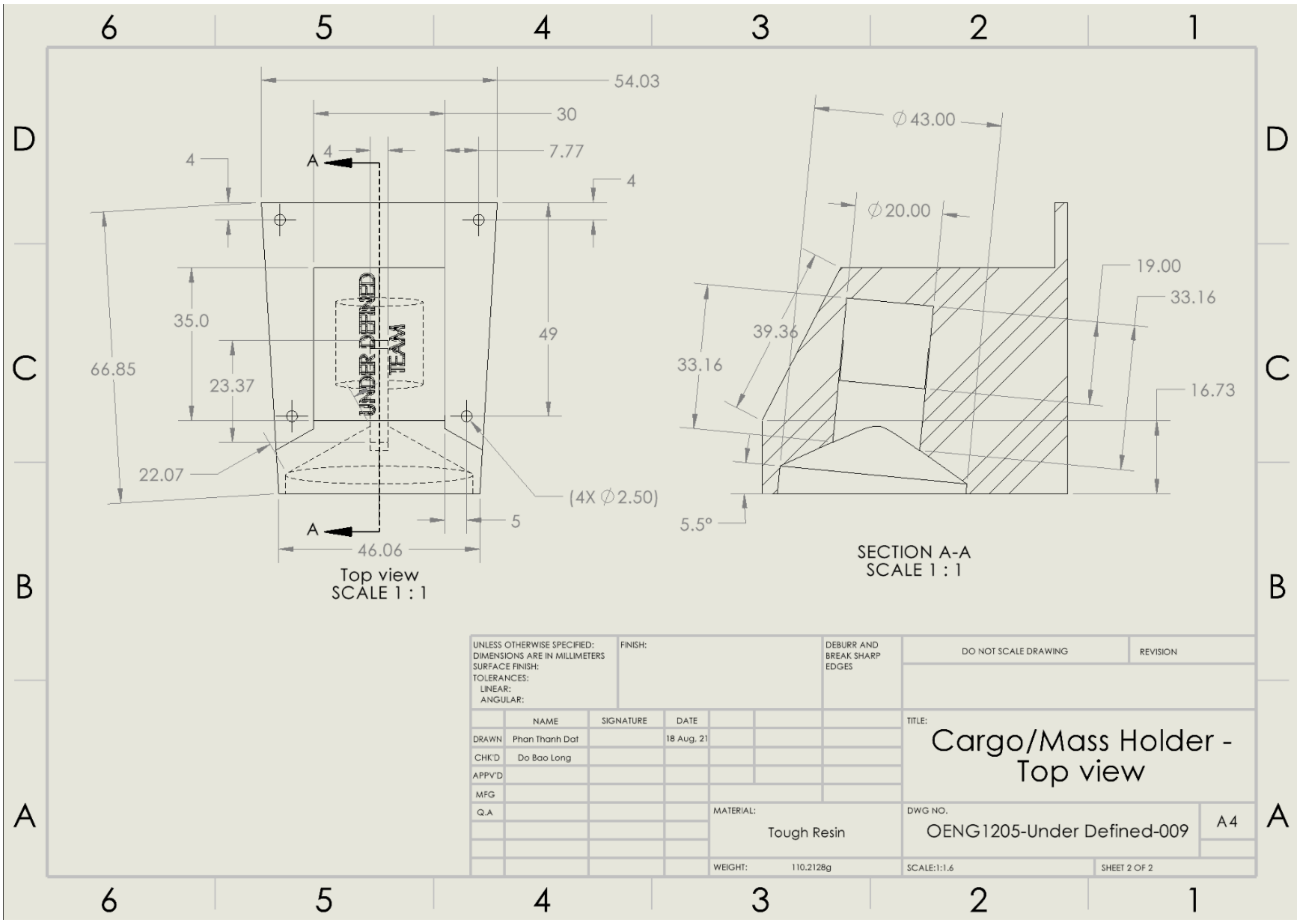


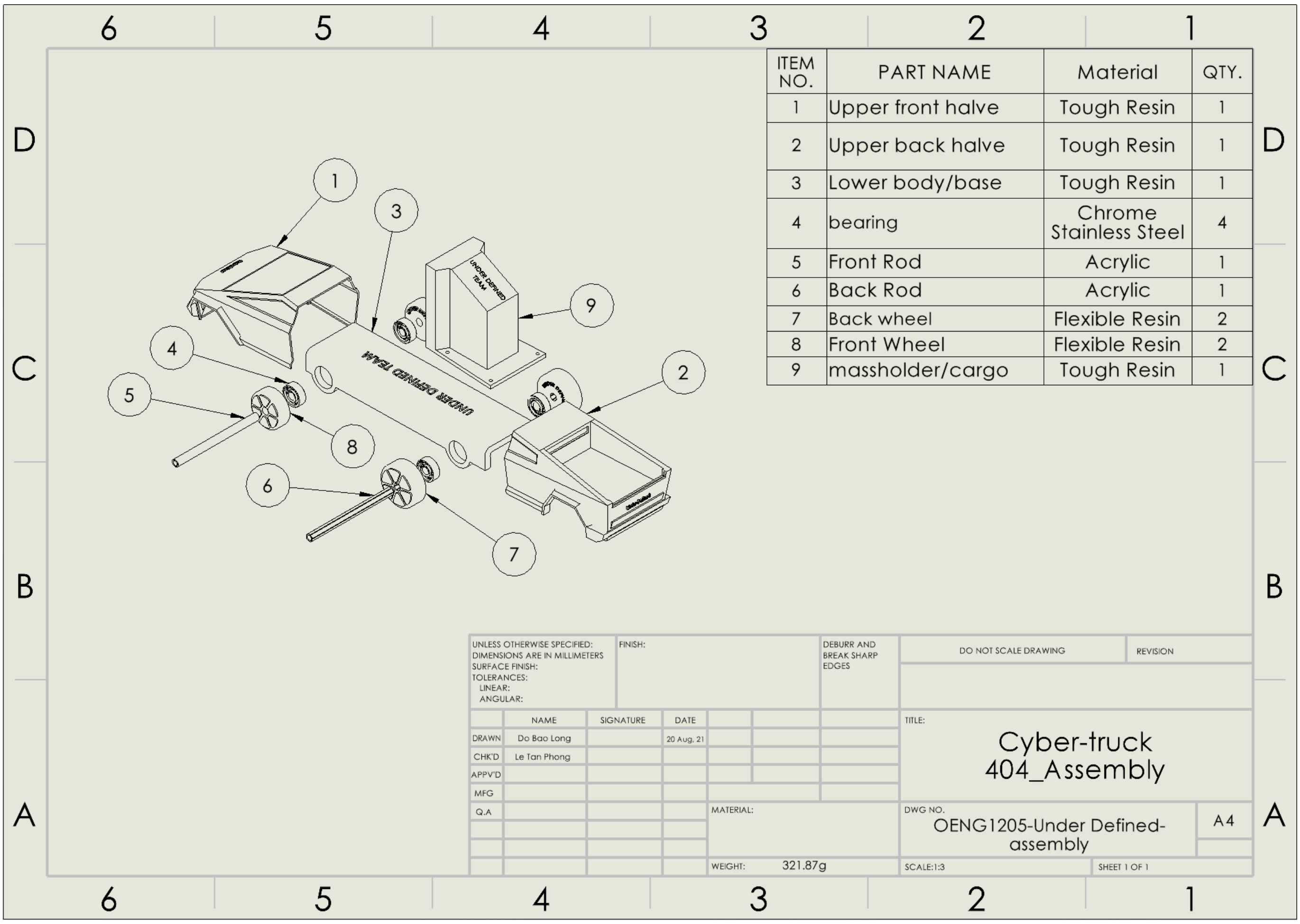

ISOMETRIC VIEW
SCALE 2 : 1
Ø 6.00
Ø 4.00
45°
0.50
UNDER DEFINED
79.00
RIGHT VIEW
SCALE 2 : 1
FRONT VIEW
SCALE 10 : 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN Hoang Thai Kiet 14 Aug. 21
CHK'D Do Bao Long
APPV'D
MFG
Q.A
TITLE:
BACK ROD
MATERIAL:
ACRYLIC
DWG NO.
OENG1205-Under Defined-006
A4
WEIGHT: 1.4291g
SCALE:1:1
SHEET 1 OF 1


Ø 29.00
UNDER DEFINED
Ø 6.00 THRU
10.00
1.00
1.00
FILLETS - R1.00 X 2
R1.00 X 12
R1.00 X 12
R12.50 X 6
R4.40 X 6
2.00
2.00
Left view
SCALE 2 : 1
Front view
SCALE 2 : 1
Right view
SCALE 2 : 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN Le Tan Phong 15 Aug. 21
CHK'D Do Bao Long
APPV'D
MFG
Q.A
TITLE:
Front wheel
MATERIAL:
Flexible Resin
DWG NO.
OENG1205-Under Defined-007
A4
WEIGHT: 7.6269g
SCALE:1:1
SHEET 1 OF 1


∅33.00
0.50
12.00
1.00
R1.00 X 12
R14.00X 6
R4.40X 6
R1.00 X 12
UNDER DEFINED
A
2.00
FILLETS - R1.00 X 2
Left view
Front view
Right view
R3.00 x 6
4.99
44.62°
DETAIL A
SCALE 4 : 1
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME SIGNATURE DATE
DRAWN Le Tan Phong 15 Aug. 21
CHK'D Do Bao Long
APPV'D
MFG
Q.A
TITLE:
Back Wheel
MATERIAL:
Flexible Resin
DWG NO.
OENG1205-Under Defined-008
A4
WEIGHT: 11.8828g
SCALE:2:1
SHEET 1 OF 1


66.73
14.89
10
51.73
70
TRUE R21.50
4
3
54.03
Front view
SCALE 1 : 1
70
49
3
Right view
SCALE 1 : 1
Isometric view
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME SIGNATURE DATE
DRAWN PHAN THANH DAT 16 Aug. 21
CHK'D Do Bao Long
APPV'D
MFG
Q.A
TITLE:
CARGO/Mass Holder
MATERIAL:
TOUGH RESIN
DWG NO.
OENG1205-Under Defined-009
A4
WEIGHT: 110.2128g
SCALE:1:1.6
SHEET 1 OF 2

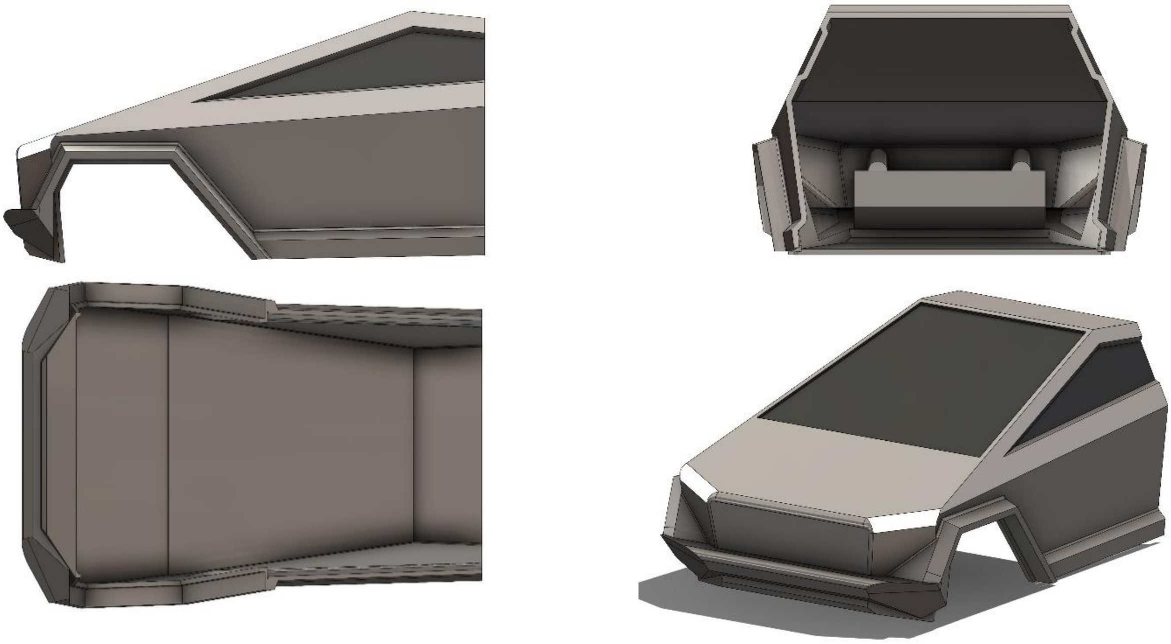


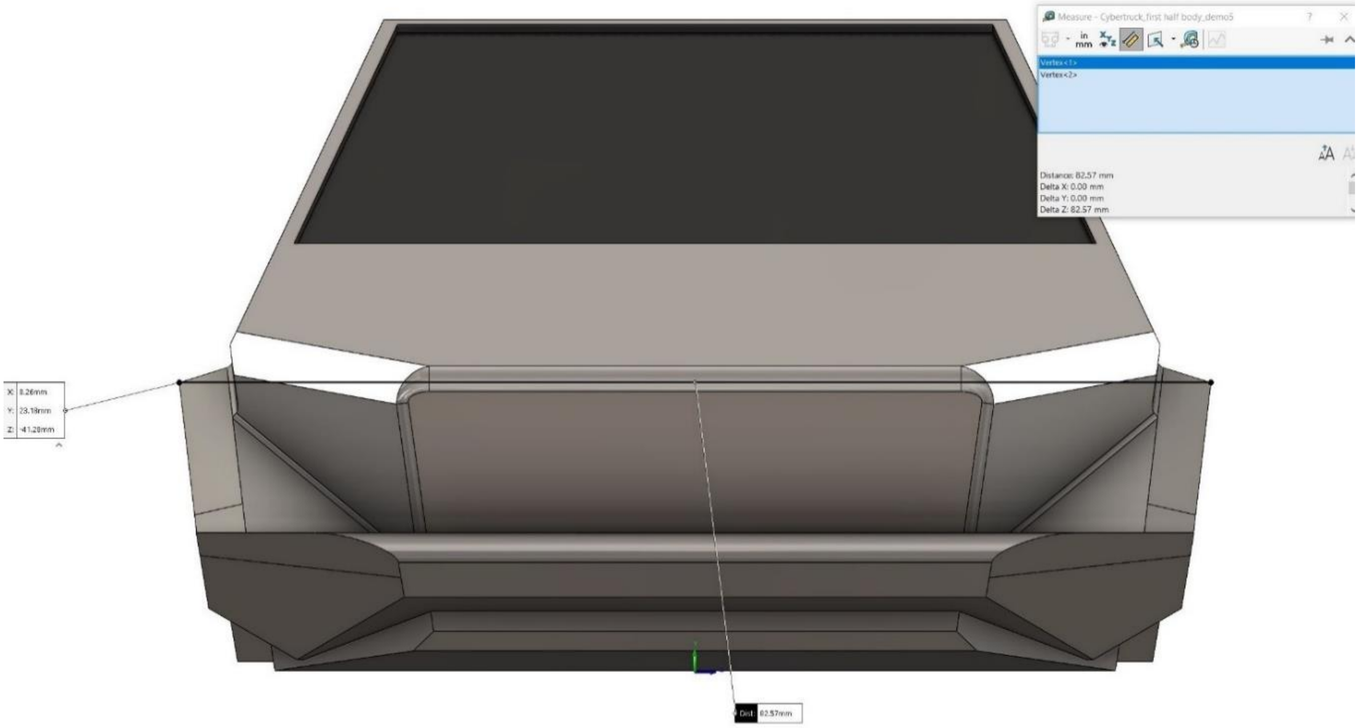


ITEM NO.	PART NAME	Material	QTY.
1	Upper front halve	Tough Resin	1
2	Upper back halve	Tough Resin	1
3	Lower body/base	Tough Resin	1
4	bearing	Chrome Stainless Steel	4
5	Front Rod	Acrylic	1
6	Back Rod	Acrylic	1
7	Back wheel	Flexible Resin	2
8	Front Wheel	Flexible Resin	2
9	massholder/cargo	Tough Resin	1

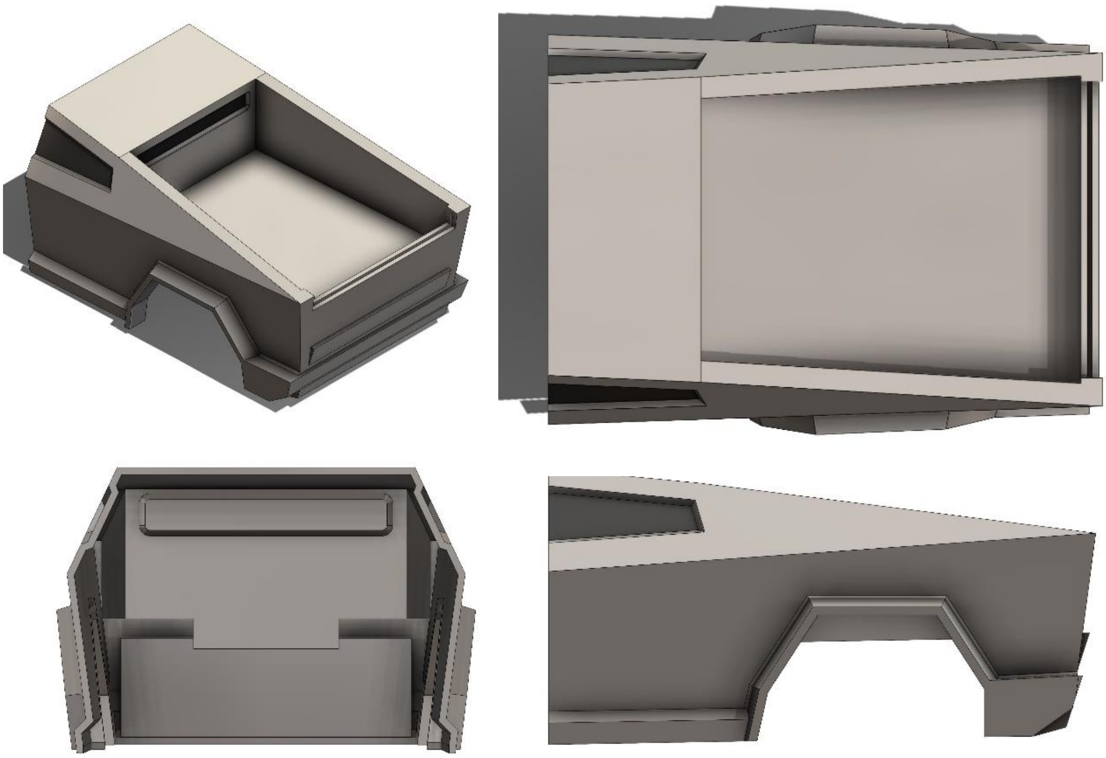
Appendix B – Tesla CyberTruck design

Appendix C – The Detailed Design of upper front halve of the Cyber-truck 404

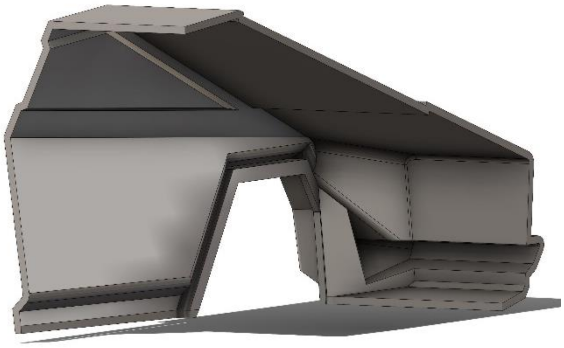


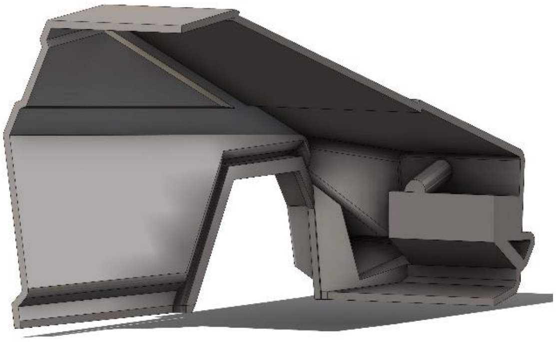


Appendix D – The Detailed Design of upper back halve of the Cyber-truck 404.

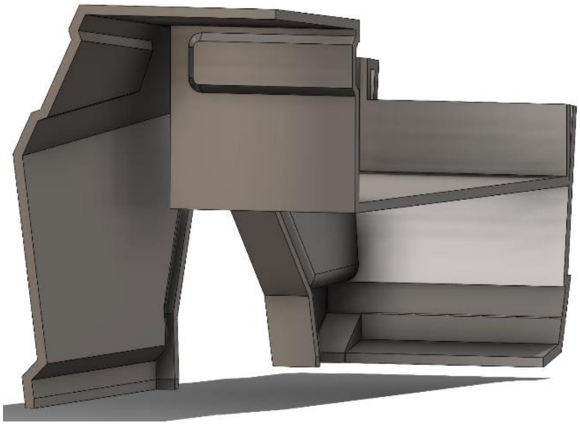


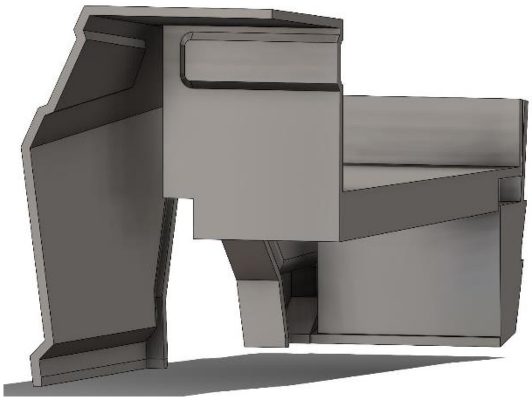
Appendix E – Before and after upgrading the inner design of the upper body.



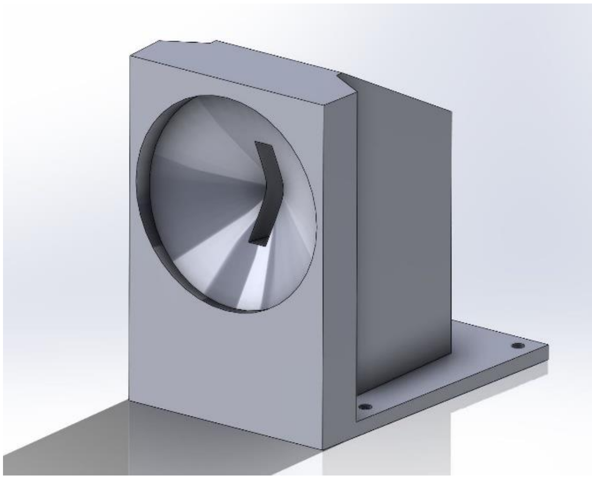


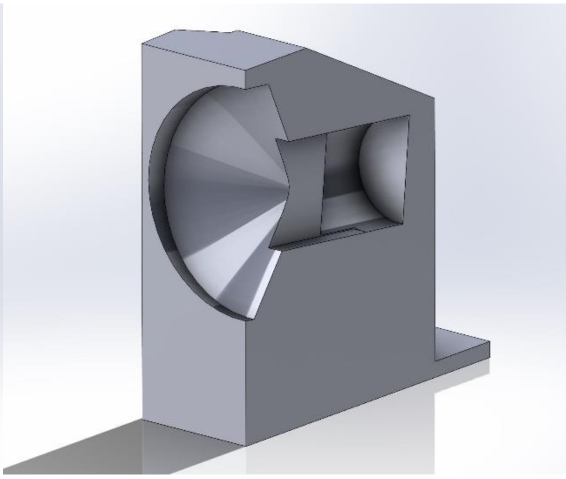
Before **After**



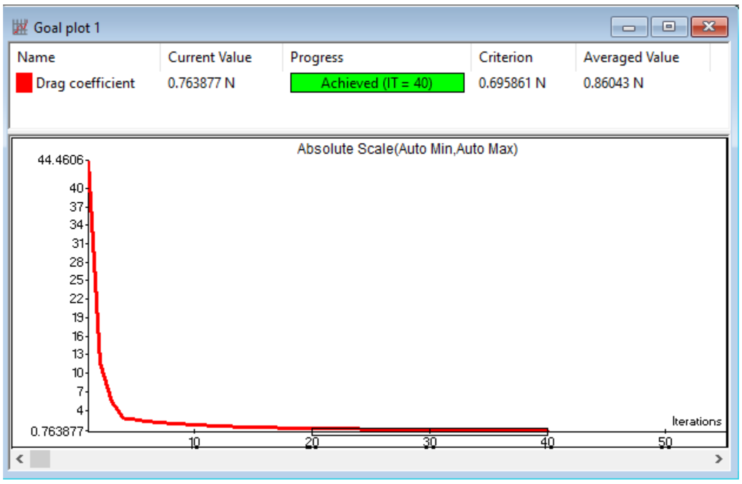


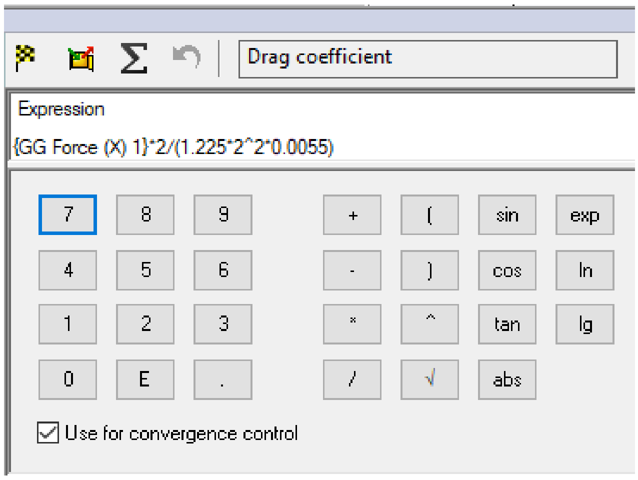
Appendix F – Cargo's construction and design. It has a lock function to hold the 500g mass tightly.

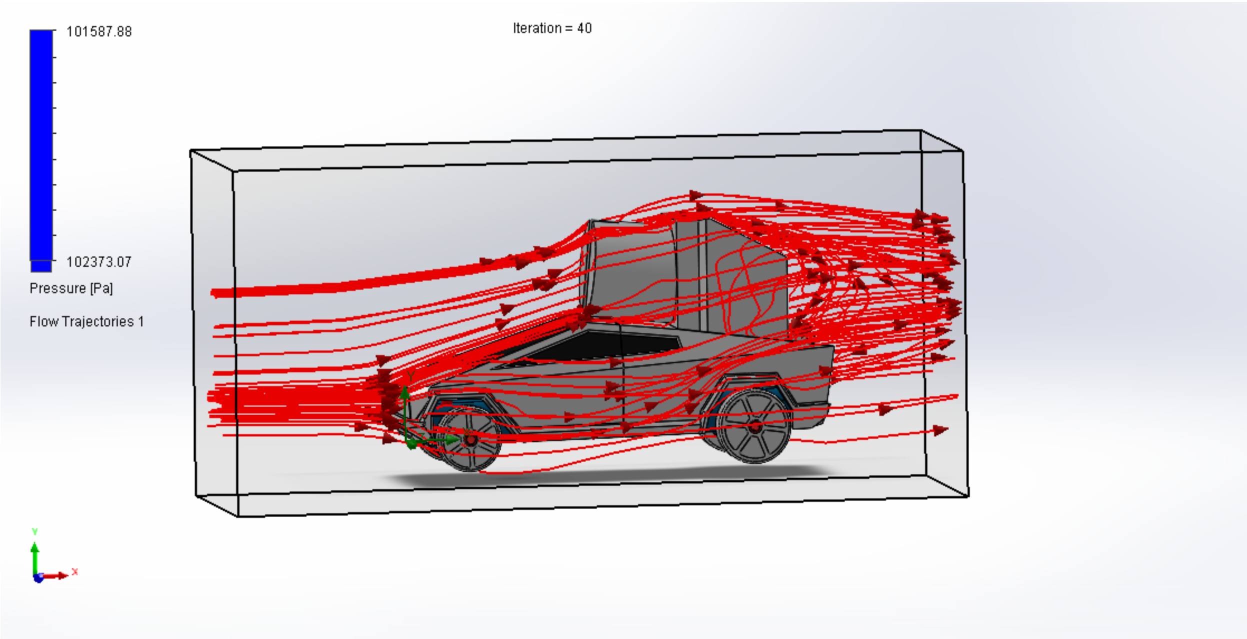




Appendix G – Calculate drag coefficient by using Solidworks Simulation







Appendix H – Bearing, it has no rubber band, and it originally contained 7 balls instead of 2 balls at present.

Appendix G – Mating Features for the Cyber-truck 404

- Mates
  - Coincident1 (Cybertruck_first half body_demo5 (2)<1>,Cybertruck_second half body_demo5 (1)<1>)
  - Coincident2 (Cybertruck_first half body_demo5 (2)<1>,Cybertruck_second half body_demo5 (1)<1>)
  - Coincident3 (Cybertruck_first half body_demo5 (2)<1>,Cybertruck_second half body_demo5 (1)<1>)
  - Coincident4 (Cybertruck_first half body_demo5 (2)<1>,Basebend<1>)
  - Parallel1 (Cybertruck_second half body_demo5 (1)<1>,Basebend<1>)
  - Parallel2 (Cybertruck_second half body_demo5 (1)<1>,Basebend<1>)
  - Coincident7 (Cybertruck_first half body_demo5 (2)<1>,Basebend<1>)
  - Symmetric1 (Basebend<1>,Basebend<1>,Front Plane)
  - Concentric1 (Basebend<1>,bearing<4>)
  - Width1 (bearing<4> ,Basebend<1>)
  - Concentric2 (Basebend<1>,bearing<3>)
  - Width2 (Basebend<1> ,bearing<3>)
  - Concentric3 (Basebend<1>,bearing<1>)
  - Width3 (Basebend<1> ,bearing<1>)
  - Concentric4 (Basebend<1>,bearing<2>)
  - Width4 (Basebend<1> ,bearing<2>)
  - Concentric5 (bearing<1>,Front_Rod<1>)
  - Coincident8 (Front_Rod<1>,Front Plane)
  - Concentric6 (bearing<2>,Back_Rod<1>)
  - Coincident9 (Back_Rod<1>,Front Plane)
  - Distance1 (Back wheel<2>,Basebend<1>)
  - Coincident11 (bearing<4>,Back wheel<2>)
  - Parallel3 (Back_Rod<1>,Back wheel<2>)
  - Distance2 (Basebend<1>,Back wheel<1>)
  - Concentric7 (Back_Rod<1>,Back wheel<1>)
  - Parallel4 (Back_Rod<1>,Back wheel<1>)
  - Distance4 (Front-Wheel<2>,Basebend<1>)
  - Concentric8 (Front_Rod<1>,Front-Wheel<2>)
  - Distance5 (Front-Wheel<3>,Basebend<1>)
  - Concentric10 (Front_Rod<1>,Front-Wheel<3>)
  - Coincident19 (Cybertruck_second half body_demo5 (1)<1>,massholder1 (2)<1>)
  - Parallel6 (Cybertruck_second half body_demo5 (1)<1>,massholder1 (2)<1>)
  - Coincident21 (Cybertruck_second half body_demo5 (1)<1>,massholder1 (2)<1>)
  - Coincident22 (Cybertruck_second half body_demo5 (1)<1>,massholder1 (2)<1>)