CLASS PROJECT DESIGNING A GRAVITY RACER

School of Science and Technology

OENG1205 - Creative Engineering CAD

Lecturer: Nguyen Chi Trung

Tutorial Section: 4 (TUE 16:30 - 18:30)

Submission Due Date: 21st August at 23:59

Group Name: 4

Date: 21st August

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I. PROJECT DEFINITION AND AIM

1. Gravity Racer's Background:

Gravity racers are the gravity-powered vehicle which does not move through motors or engines but only through slope of the ground, wheels and gravitational force. It was recorded that the Gravity racers originated from Frankfurt, Germany back in 1904. It appeared as an entertaining game or competition where young and old players would build gravity racers with juncked wooden soap crates and wheels which would be then competed for the speed. [5] Then, in 1933 more popularity was gained throughout the US as a name of "All-American soap box Derby" [4]. As popularity for soap box races increase, soap box cars have evolved with creative designs, engineering mechanisms and building materials like metal and fiberglass with an anticipation to take over the winner title.

2. Project Objectives and Specifications:

This report is a design report which proposes our group's design of the gravity racer aiming for determining the maximum speed and weight. All members of the group have committed to develop a design by applying the knowledge gained from the CAD course and calculate the maximum speed considering the variables with application of physics and mathematical theories. This report will begin with the provision of a plan of development, followed by the design mechanism and calculations, and finally a description of our racer. Detailed image and the drawing of the vehicle was included in the appendices of the report.

3. Plan to execute the project:

- **Conceptual design**

The gravity racer mainly has three components with a total of seven parts: the hull, 4 wheels, and 2 axles. Each part should fit in the shape of a 13 x 13 x 13 cm box. Each of the axles connects with two wheels. Eventually, we connect two axles to the hulls to produce a complete gravity racer. This gravity racer should look like in figure 1. It took 1 days for us to complete the conceptual design of racer.

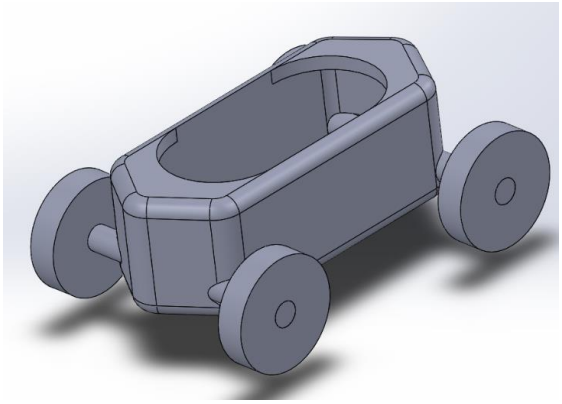


Figure 1

- **Detailed design**

The soap car is a main part of a gravity racer. We use SOLIDWORKS to create a rectangular shape based on a 13 x 13 x 13 cm box. Then we create the hull with a thickness of 42 mm by adding each fillet triangles with two holes are added next to each side of the box. At least one 500g PASCO hooked mass should be placed on the hull, therefore, we make a huge empty place in the middle of the soap car to be able to hold two. Moreover, each axle with thickness of 93mm must be able to hold and make two wheels rotate in order to move the gravity racer on a PASCO race track of 10 cm. It takes 5 days to complete the design.

- **Manufacturing and testing**

When the design of the gravity racer is finished, the next step is going to manufacture it. The hull and two axles will be affected most by the PASCO mass, therefore, tough resin must be used for the 3D printer. The 4 wheels are made of the Non-Translucent Acrylic material in order to move the gravity racer. Since the manufacturing is done, the complete gravity racer is ready to test. Theoretically, the cart should be able to move on the PASCO track when carrying a PASCO hooked mass since it meets all the requirements of material.

II. DESIGN MECHANISM AND CALCULATION

1. Gravity Racer's mechanism:

The gravity racer has 3 main components: the hull, axles and wheels. There are three goals for the design: to go as fast as possible, then after leaving the slope the car can go further 1 meter, and withstand a hit to an Acrylic wall.

- First, for the Gravity Racer to goes as fast as possible, we need help from the gravitational force:

$$F=m*g*Sin(theta)$$

The gravitational force depends on the mass of the car. The heavier the car, the bigger the gravitational force and the faster the car goes down the slope. For this reason, we designed the car to carry the most weight but still satisfy the requirement of the project, which is two weights for the total mass of 1kg.

- Second, the car needs to be able to travel at least 1 meter after exiting the slope. And the way we make sure that the car can do that is to minimize the rolling resistance force and drag force. The rolling resistance is directly proportional to the Mass Moments of Inertia:

$$I = 1/2 * M * (R1^2 + R2^2)$$

To reduce the mass moment of inertia, the outer radius of the wheels will be small and the inner radius is connected to an axle with the same radius so basically the inner radius is 0. For the drag force most of the variables cannot be change:

$$Fd = Cd *(p*v^2)/2 * A$$

Except for the variable A frontal area, more frontal area means more drag force, so we built the car width just enough to carry the weights. We try to save as much space as possible to decrease the frontal area. In addition we smooth out the edges to hopefully improve the drag coefficient to the average of 0.5. After minimizing the rolling resistance and drag force, we have calculated the theoretical maximum speed and acceleration. And according to the calculations below, the car will be able to travel further than 1 meter in a 5 degree slope, so the car will definitely meet the requirement for higher slopes.

- Finally to prevent the car from falling apart when hitting the Acrylic wall we choose the hull material to be tough resin which has balance strength, flexibility and can undergo brief periods of stress. We also smooth out all the edges to avoid weak structures. The wheels are made out of Acrylic which has the tensile strength of 10000psi or 7kg force per square millimeter so the Gravity Racer’s 4 wheels can carry the 1kg weights.

2. **Calculation**:

Tough Resin Density = 1.11 g/cm3

Non-Translucent Acrylic = 1.19 g/cm3

Hull mass = 84.828 * 1.11 = 94.16g

2 Axles mass = 5.916 * 1.11 * 2 = 13.13g

4 Wheels mas = 11.93 * 1.19 * 4= 56.79g

2 weights on car mass = 1000g

Total mass = 94.16 + 13.13+56.79 +1000 = 1.164 kg

Frontal Area = wheels 800mm2 + axle 180mm2 + body 2226mm2 = 0.00326m2

Maximum speed of the Gravity Racer on a 5 degree plane

- Gravitational Force:

Fg = m * g * Sin(theta)

Fg = 1.164 * 9.81 * Sin(5) = 1 N

- Rolling Friction Force of wheels [1]

Fr * R = ½ * m* R^2

Fr = ½ * m * R

Fr = ½ * 0.014 * 0.02 = 0.00014 N

- Drag Force:[3]

Fd = Cd * p*v^2/2 *A

Fd = 0.5 * 1.225*v^2/2 * 0.0032

- Net Force on car in inclined plane:

Fnet = Fg - Fr - Fd

m*a = 1 - 0.00014*4 - 0.5 * 1.225*v^2/2 * 0.0032

a = (1 - 0.00014*4 - 0.5 * 1.225*v^2/2 * 0.0032)/1.164

- Velocity and the end of the slope:[2]

vf^2 = vo^2 + 2ax

v^2 = 2 * (1 - 0.00014*4 - 0.5 * 1.225*v^2/2 * 0.00326)/1.164 * 1

v = 1.31 m/s

- Net Force on car in normal plane:

Fnet = F - Fd - Fr

Fnet = 0 - 0.5 * 1.225*1.31^2/2 * 0.00326 - 0.00014*4 = -0.00227 N

- Car acceleration on normal plane:

a= F/m

a= -0.00227/ 1.164 = -0.00195 m/s2

- Car velocity when hit the wall:

vf^2 = vo + 2ax

vf^2 = 1.31 + 2*-0.00195*1

vf= 1.14 m/s

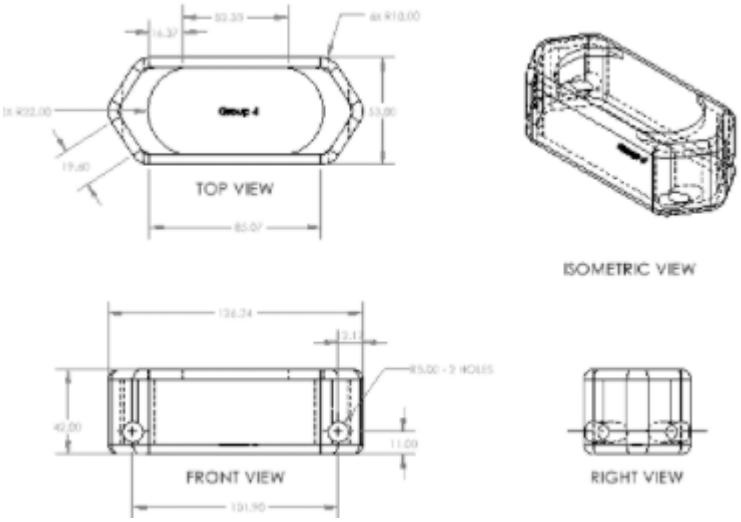
3. Ideal variables:

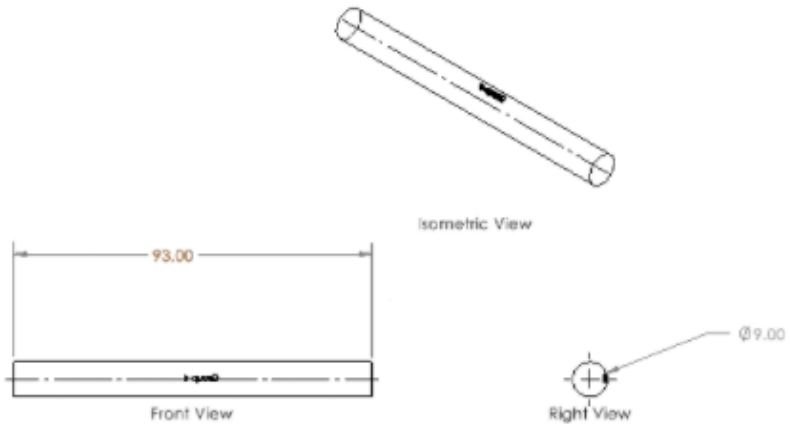
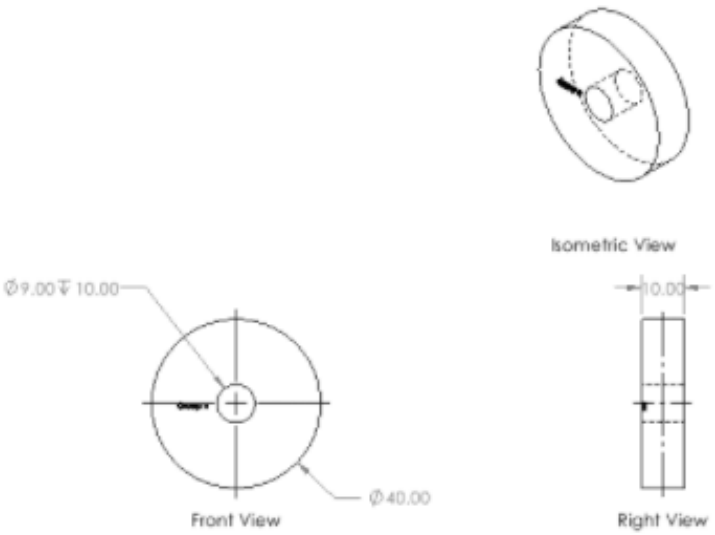
The ideal variables that we try to achieve in this design are:

- A pure rotational motion, the acceleration at the contact point between the wheels and the surface is 0 which means the wheels are rolling without slipping.
- Drag coefficient, a dimensionless experimental aerodynamics value is at most 0.5.

III. DEVICE DESCRIPTION

1. Lists of Components:

Part No.	Description	Material	Manufacturing method
1	**Hull (Quantity: 1)**  -The Gravity Racer's hull is the main base that every other part is attached to -There is space inside the hull for holding the PASCO hooked mass not to fall out of the Racer during the race - There are 4 holes on the hull to put the axles through it	Tough Resin	3D print
2	**Axle (Quantity: 2)**	Tough	3D print

	 -The axle is the connector of the 2 wheels - which attaches them to the hull	Resin	
3	**Wheel (Quantity: 4)**  -The wheel is a part that makes the Gravity Racer move. -With hollow cylinder shape, the wheel allows the axle to get through and connect it with other parts.	Non-Translucent Acrylic	Laser Cut

- Hull:
    - The hull has dimensions of 42mm height, 53mm width (fluctuate through the depth of the hull) and 116mm depth
    - The dimensions of linear slot-shaped hollow on the top of the hull:
        - Distance between two centers of arcs: 43 mm

- Radius of each arc: 22 mm
- The length of the hollow = 43 + 2*22 = 87 mm
- Width of the slot: 43 mm

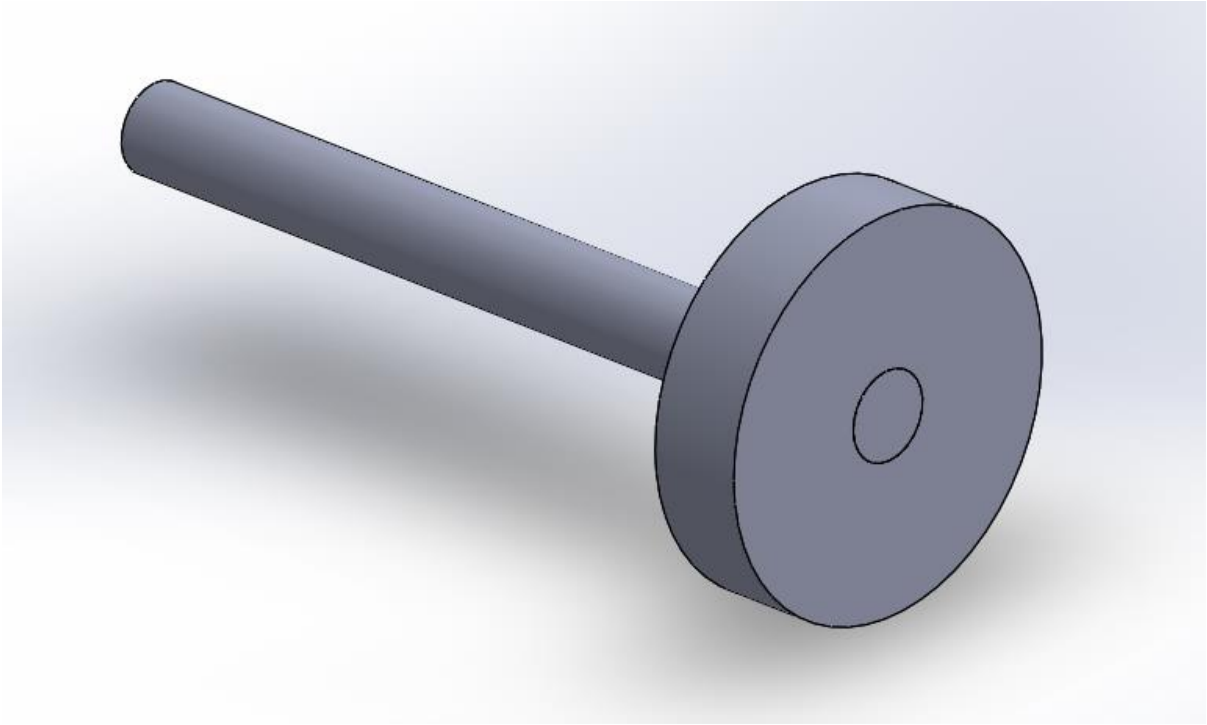
⇒ With the length of 87mm and the width of 43mm, the hollow is fit for 2 PASCO hooked masses with diameters of 43mm. This will ensure that the mass would stand steadily inside the gravity racer while it is moving downslope. Note that the height of the hull is equal to 42mm - which is the same as the height of the cylindrical part of the hooked mass.

- The 4 holes through the hull are made from the 10mm-diameter circle on a flat surface that is coincident with the left or right side of the body.

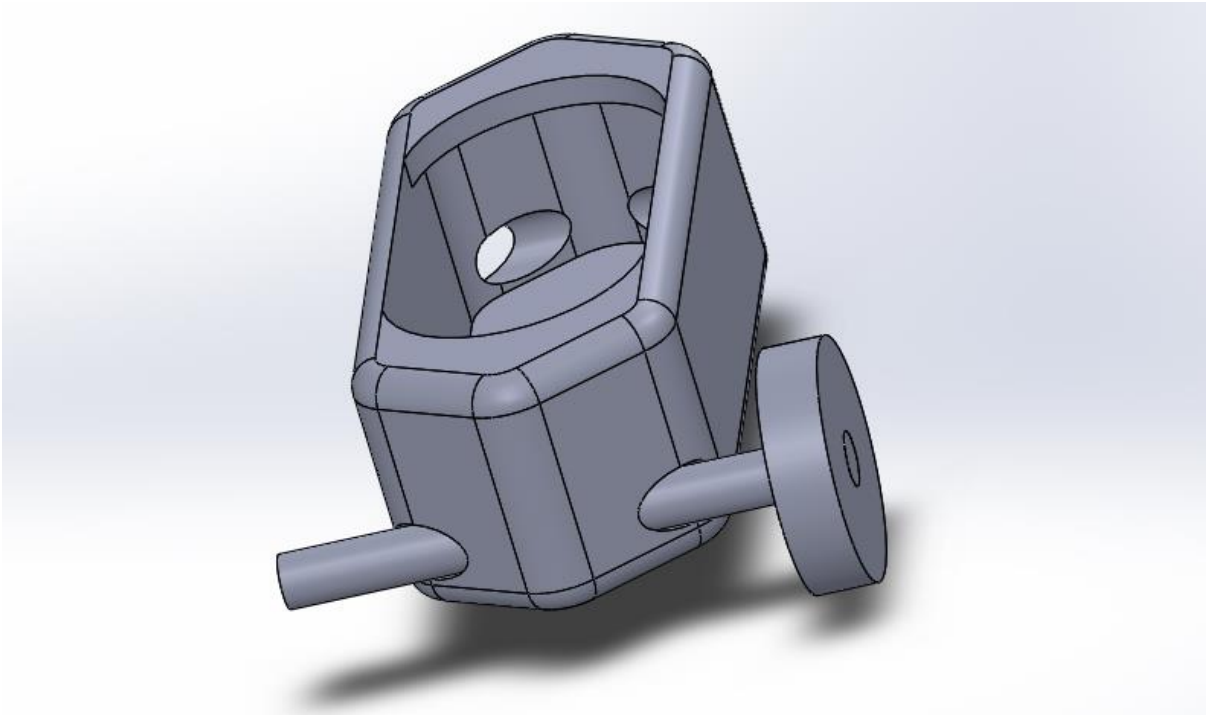
- Axle:
  - The axle has dimensions of 93mm length and 9mm-diameter circle of the two ends.
  - With 93mm long, the length of the axle is supposed to be the total width of our car.
  - The two end circles have the diameter that is a little smaller than the one making the holes on the hull so that the axle can get through it as well as rolling during the race.
- Wheel:
  - The wheel has dimensions of 9mm-diameter inner circle and 40mm-diameter outer circle with the thickness of 10mm.
  - With 9mm-diameter of the hollow part - which is equal to the diameter of the axle, the wheel can stick into the axle and be connected with another one. This leads to the same rolling motion of the two wheels that are connected by an axle.
  - As mentioned before, the width of the hull is 53mm and the total width of our gravity racer is 93mm. The 53mm hull width with the 20mm thickness of two wheels takes up 73mm in width. Therefore, there should be at least 10mm space separating the hull and the wheel. This could minimize the risk of collision between these two parts.

2. Gravity Racer Assembly:

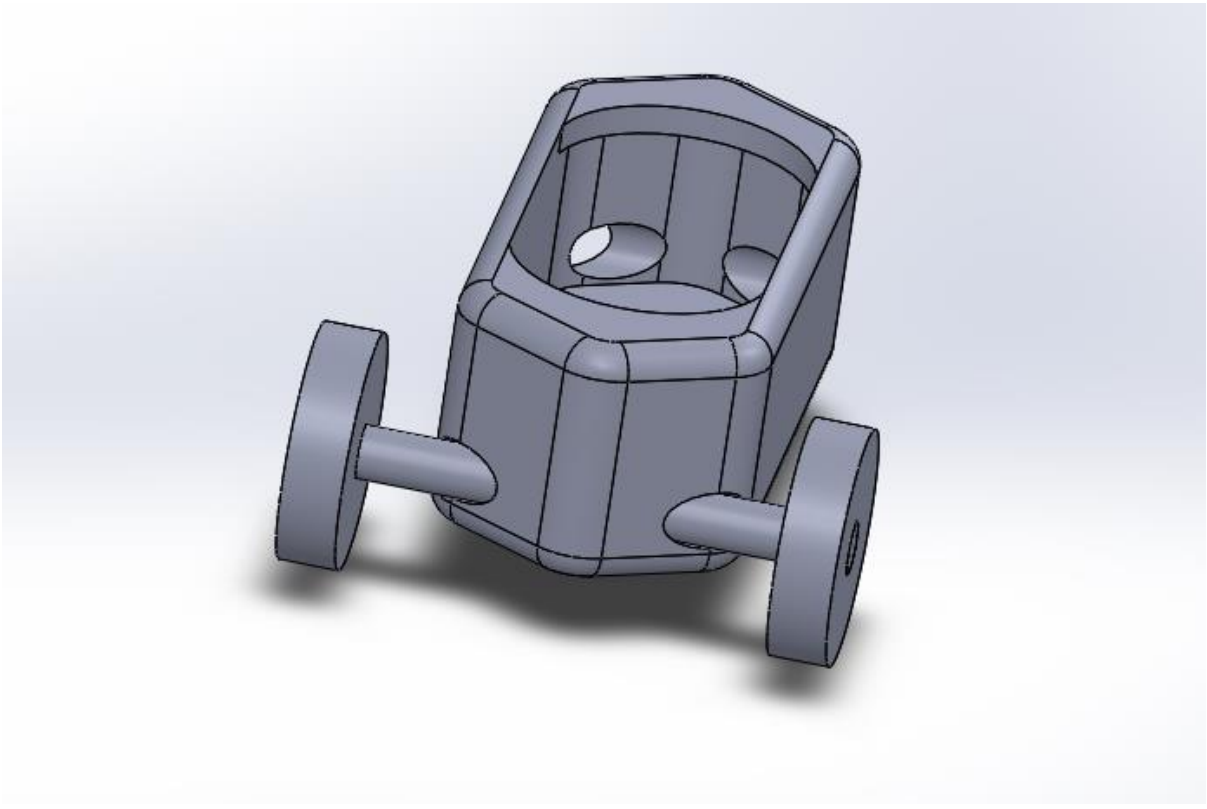
- Attach one wheel to the end of an axle and fixed by using a glue gun



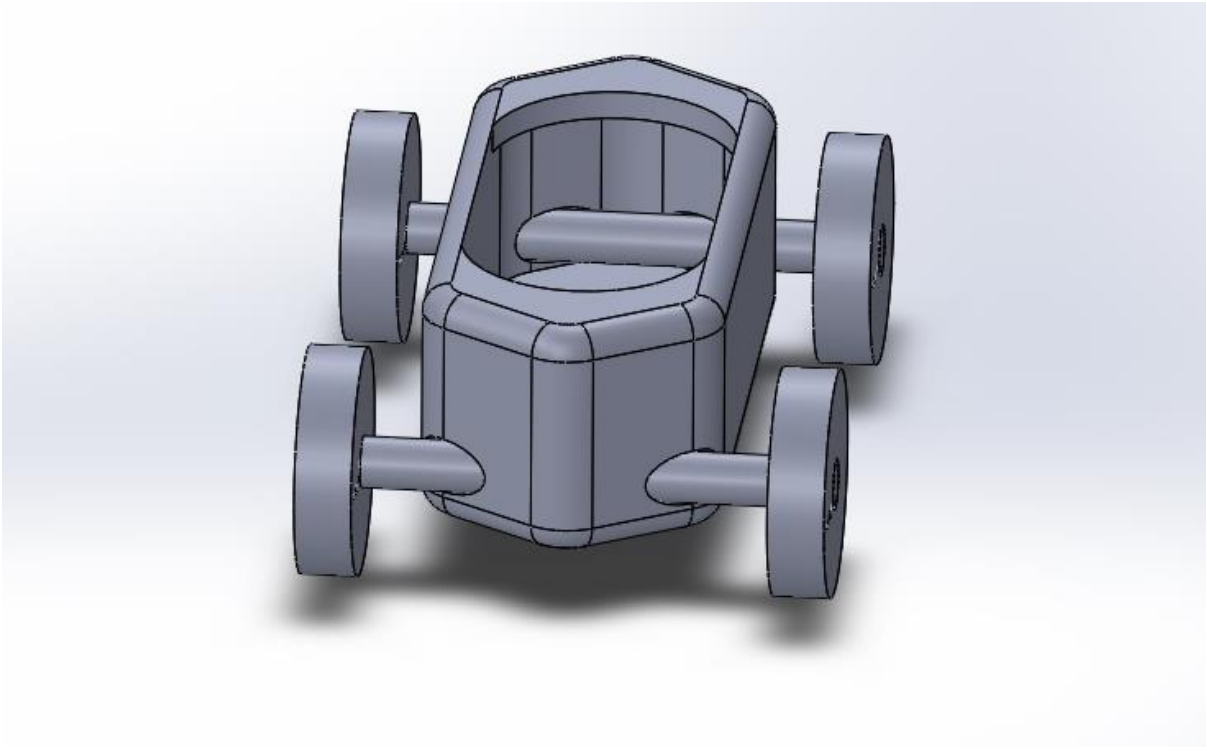
- Slot the axle all the way through the hole on the car hull



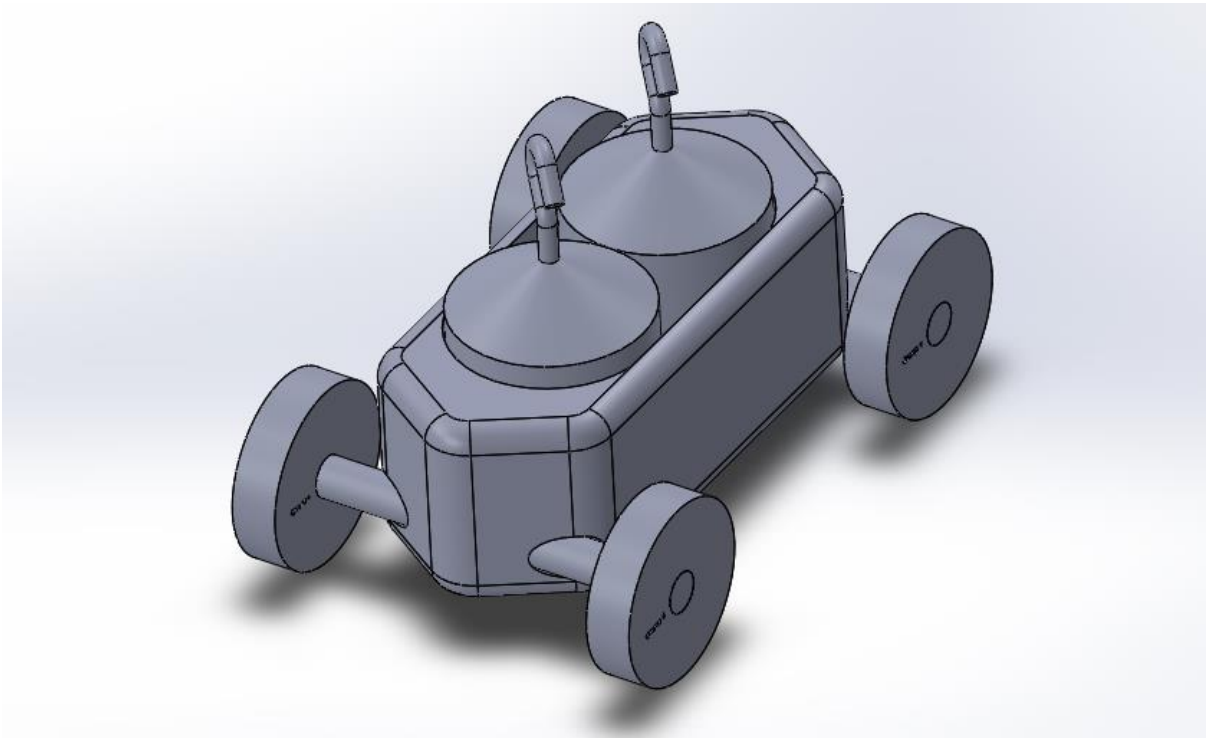
- After that, glue the wheel to the other end of the axle



- Repeat the process for the other hole.



- Place the 2 weights into the slot-shaped hollow on the top of the hull



IV. REFERENCES

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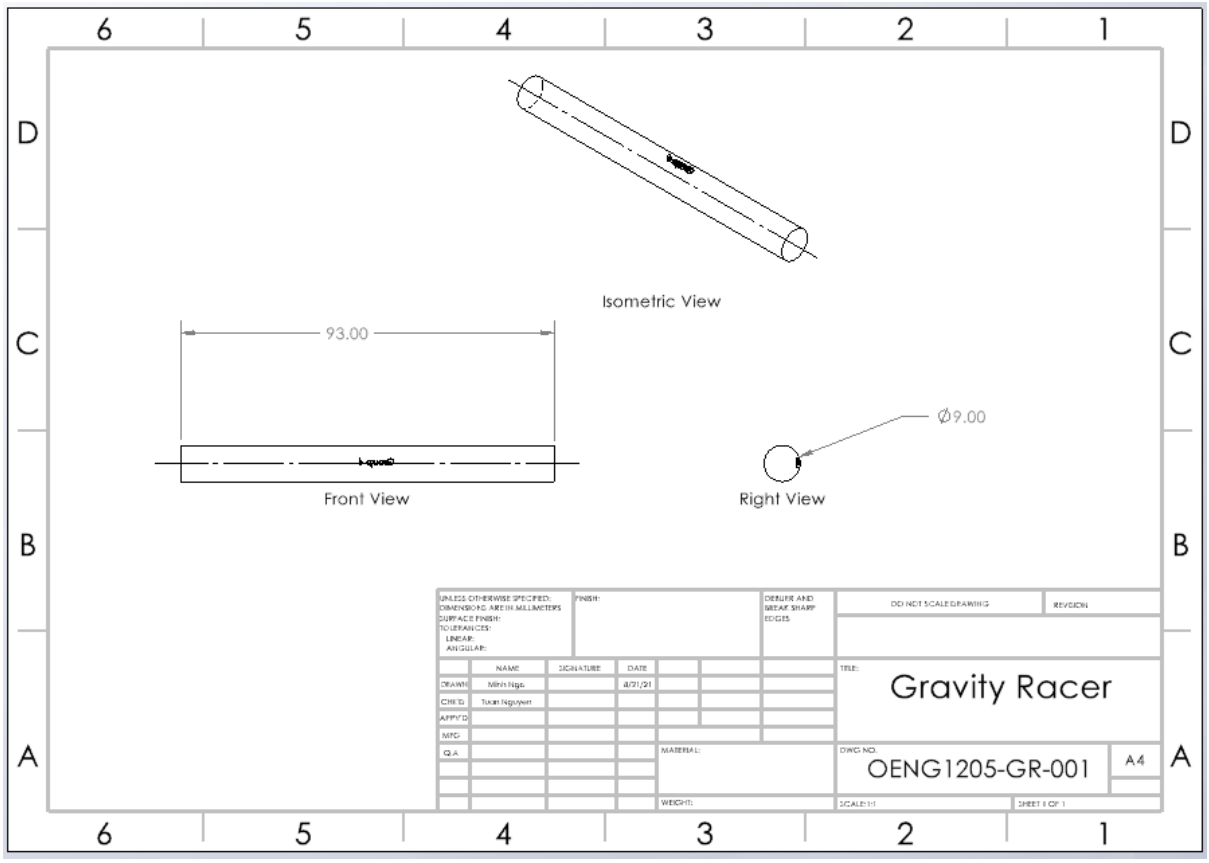
V. APPENDIX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Gravity Racer
OENG1205-GR-001
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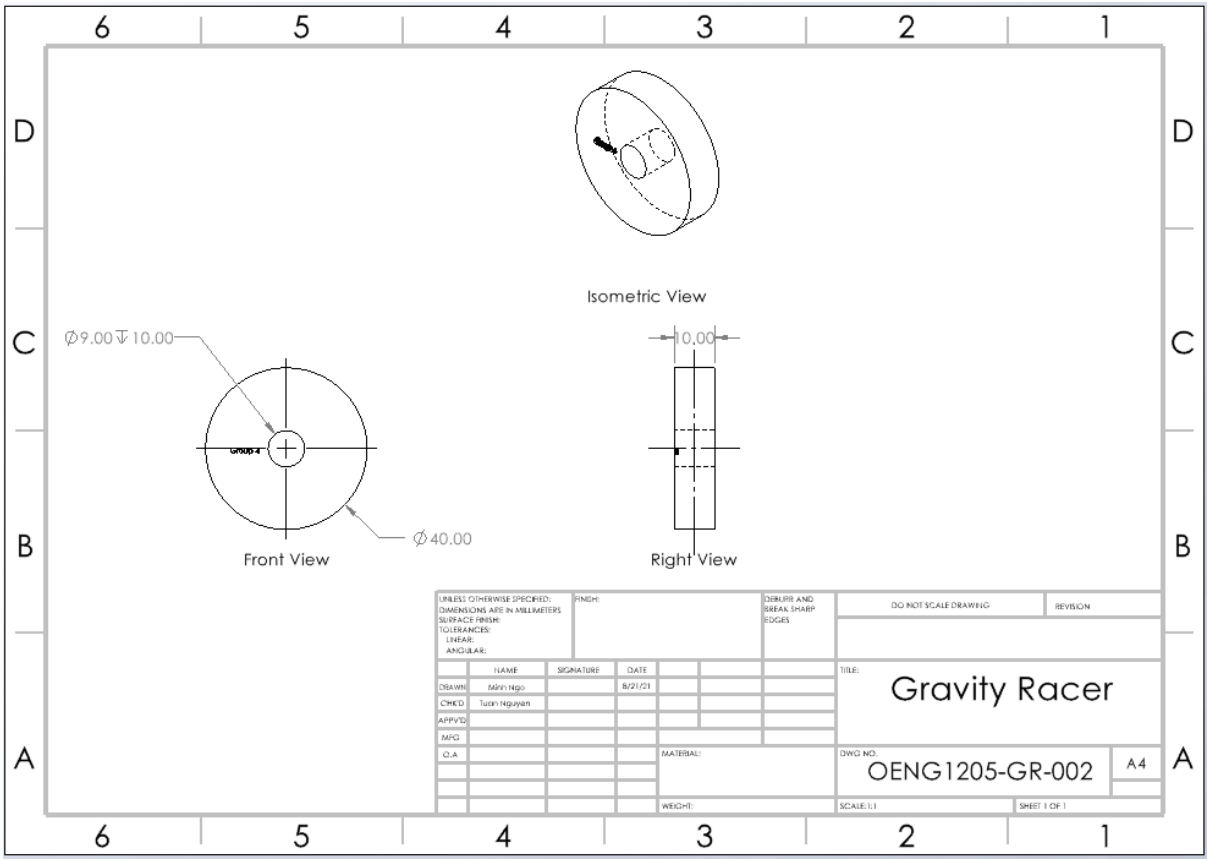
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CHK'D
Tuan Nguyen
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OENG1205-GR-002
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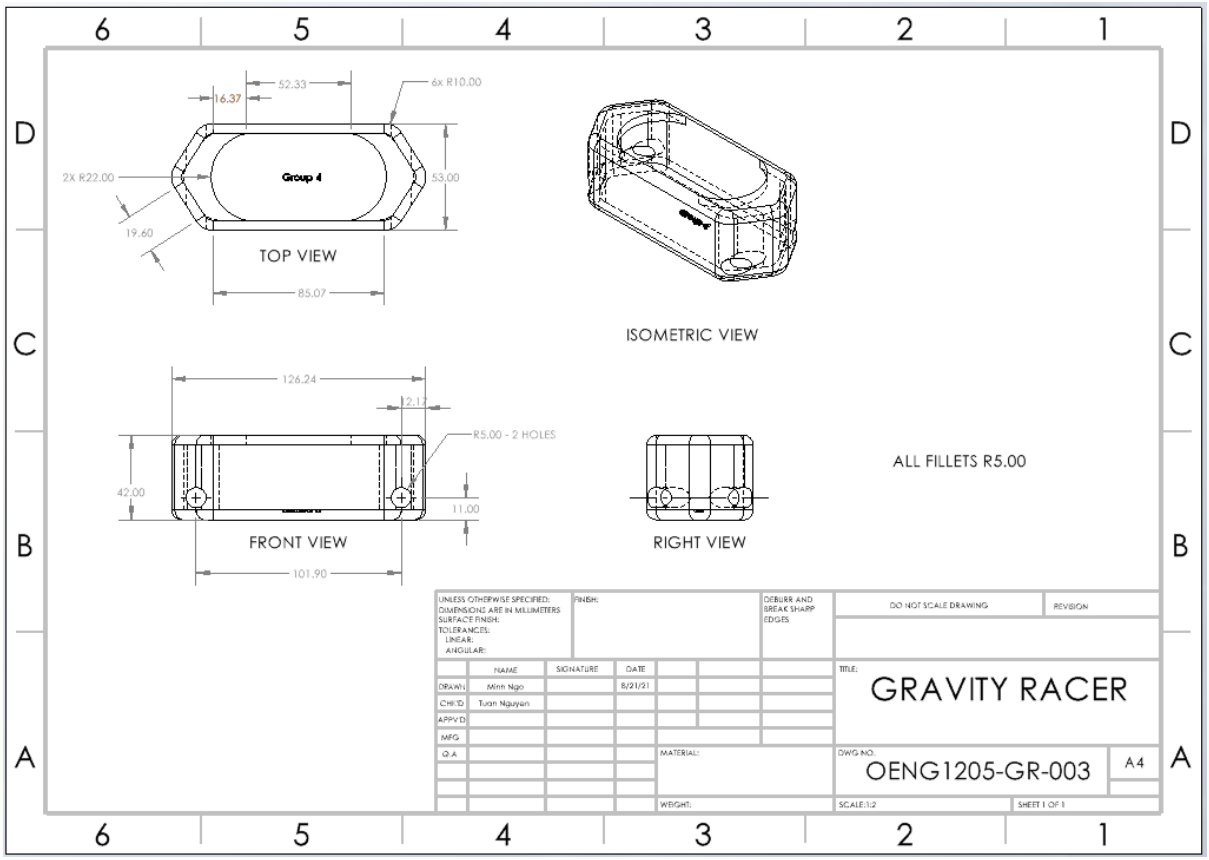
SHEET 1 OF 1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85.07
ISOMETRIC VIEW
126.24
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