University of Wales Trinity Saint David



Wales Institute of Science & Art

Group Project second assignment

Integrating project (ACHA4008)

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Group Project Second Assignment

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Introduction

In this report the aim is to showcase the final design of the soapbox project researched in part one of this assignment.

This report will include a section about the final design of the soapbox, an analysis of the design, and figures generated from equations to show how the soapbox will work (e.g. mass, acceleration.) with a conclusion at the end summarizing the outcome of our project.

The final design was created in CAD software using SolidWorks to visualise how the design would look with all the accurate dimensions.

Aims and Objectives

Our aims were twofold, to research the best ideal materials for different applications, and to design a functional soapbox vehicle that fit the specifications provided.

During our first stage of research, we assessed which materials would be ideal, in a no-expense spared situation. Naturally, for the second stage of our development, we focused on a balance between affordability, performance, and crucially, the safety of the driver.

To recapitulate, we strived to create a design that was lightweight, durable, aerodynamic and safe should there be an accident during the descent.

CAD Drawings

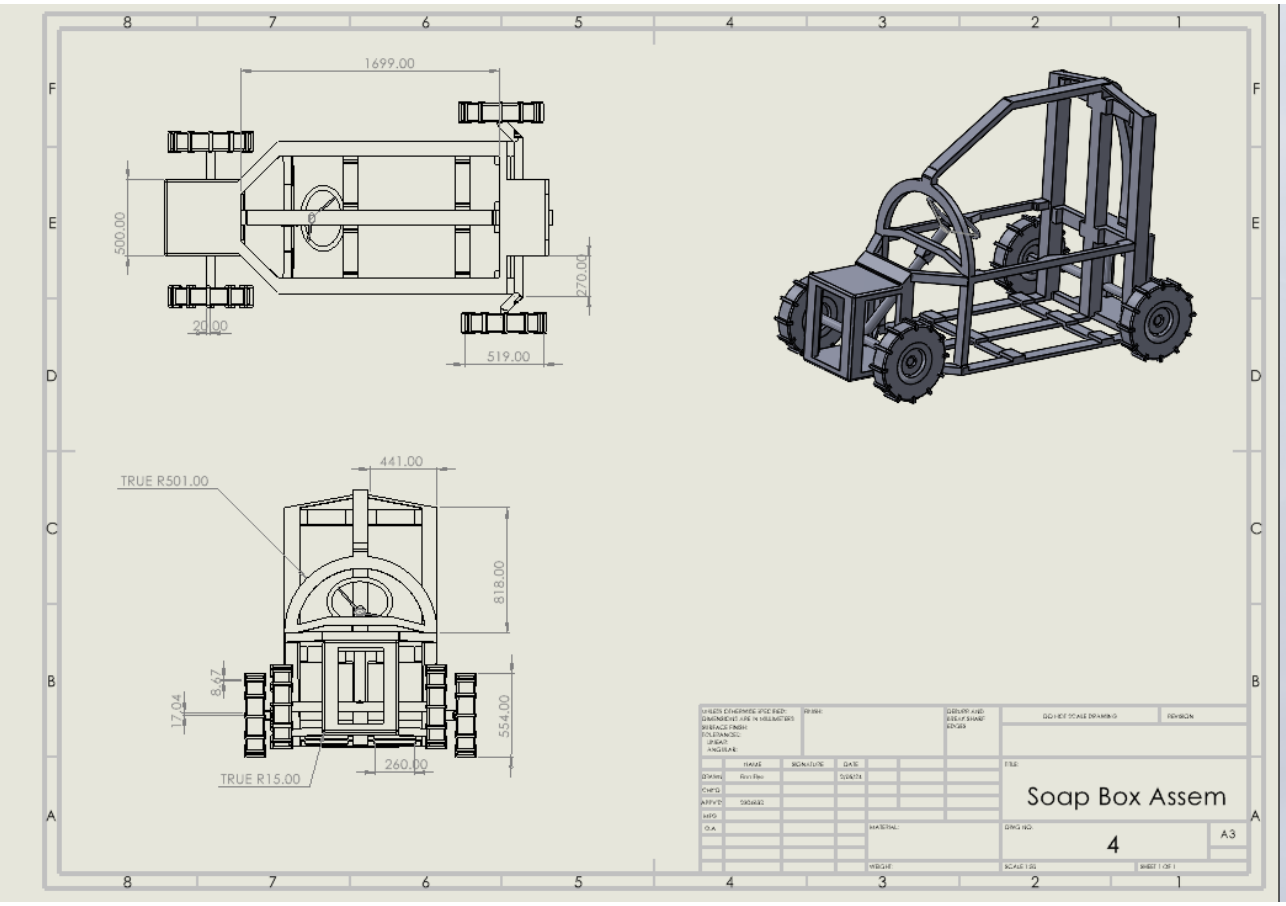


Figure 1-1 CAD Drawing showing the Assembly of the Soap Box (Finn Flye, 2024)

We have adapted the design from our previous drawings for our finalized idea of the Soapbox that we wish to produce, due to its improved aerodynamics. The rectangular frame ensures protection of the driver, we have opted to round the edges for a more aerodynamic frame.

Due to our design being crafted from steel, our Soap Box will be on the heavier side. A benefit of this feature is the increased downforce and stability during the descent.

In the previous report we stated that it would be the maximum length and width that the regulations allow. However, when creating the chassis, we decided to go with a width of 1000mm to ensure we had enough space for the wheels. With the wheels the total width is 1461mm.

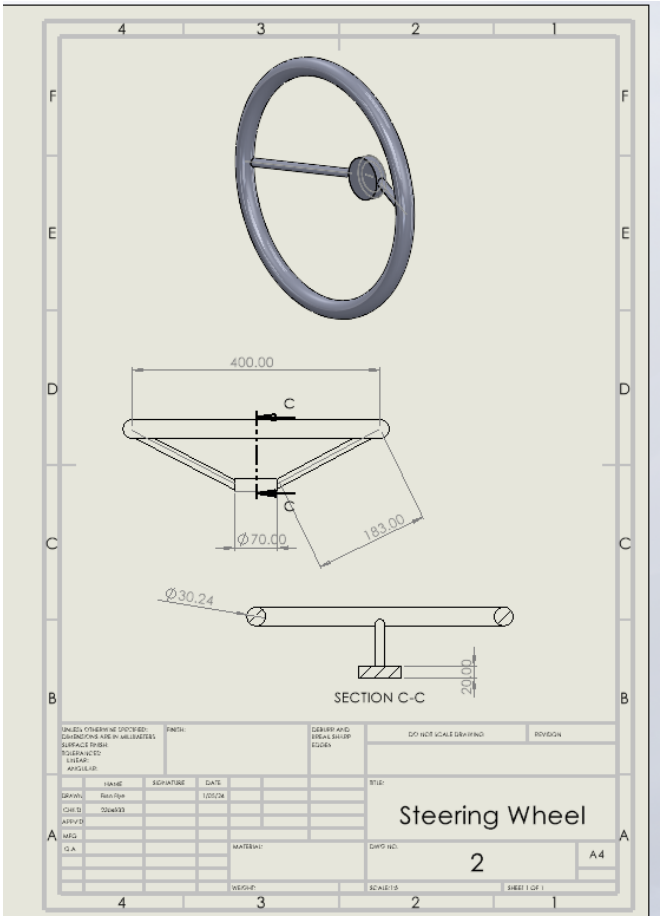


Figure 1-2 CAD Drawing showing the design of the steering wheel (Finn Flye, 2024)

The design we created for the steering wheel is shown here in this engineering drawing. To create this design, we referenced (MAHTABALAM,2016) as we wanted a simplistic design, but weren't sure on how to create one. By modifying the dimensions and arms of the wheel we were able to create this. This steering wheel proved efficient, allowing ample hand room for the driver to make adjustments without compromising his positioning.

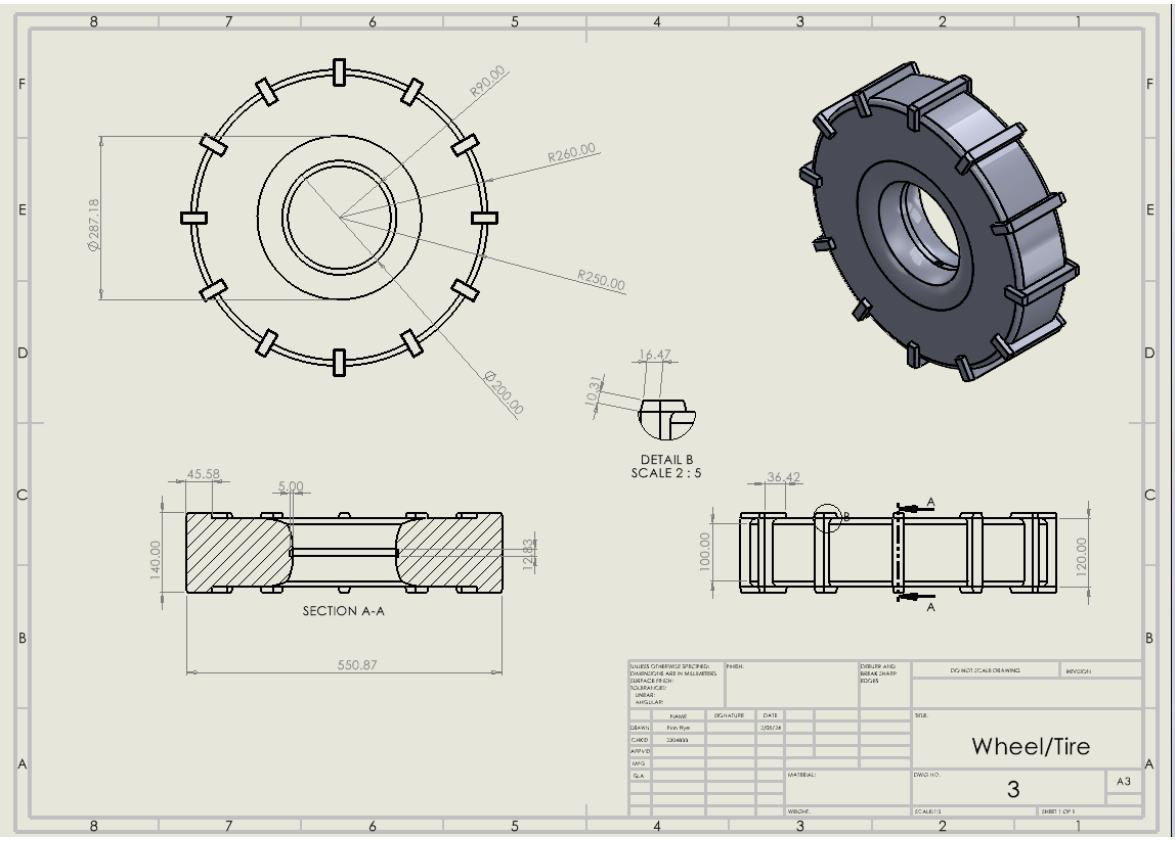


Figure 1-3 CAD Drawing showing the design and section view of the Wheel/Tire (Finn Flye, 2024)

This was the design that we created for our wheels, we wanted a wheel/tire that would be relatively wide to ensure the weight of the driver and chassis were supported. We also made a conscious effort to keep the frame above the 50mm minimum height from the starting ramp.

These wheels should be effective on any course, the gaps between each thread provide ample grip in any terrain and should allow the vehicle to go over any bumps or obstacles.

For this design we referenced (Issac Alaka, 2015) as we have never made a tire before. This allowed us to implement some design aspects and further refine them.

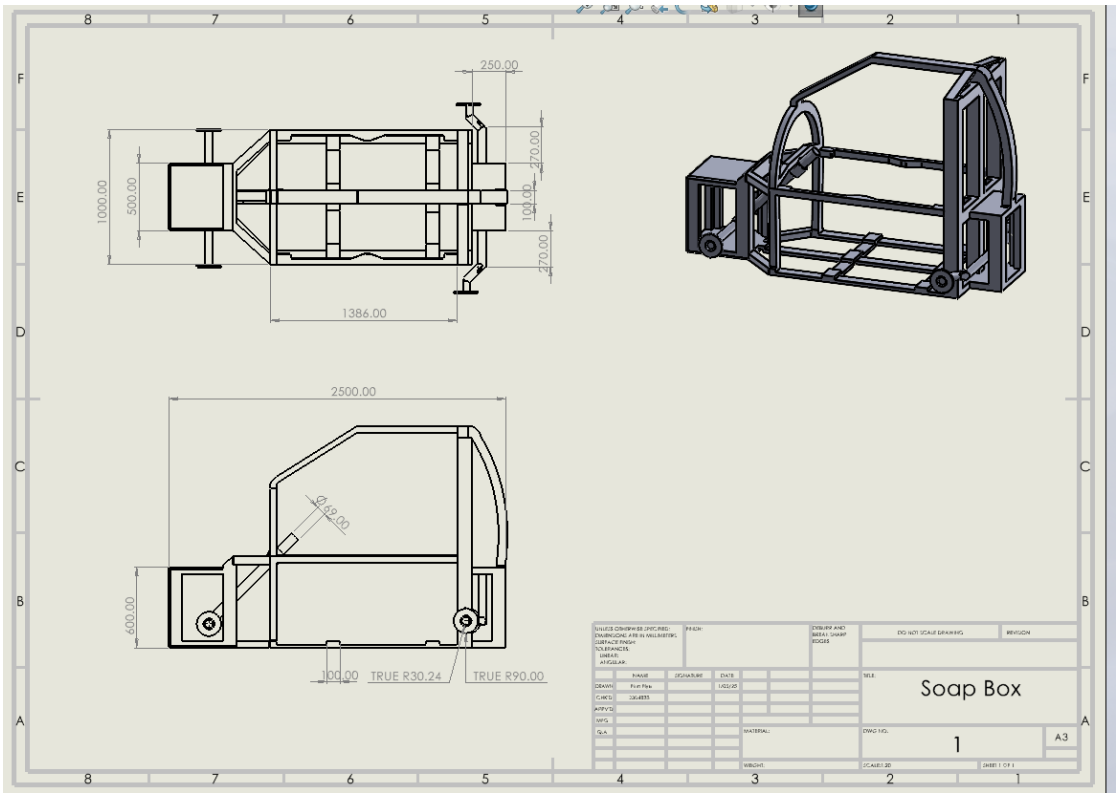


Figure 1-4 CAD Drawing showing the chassis of the Soap Box (Finn Flye, 2024)

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The design of the Soap box chassis derives from our previous report as this design was collectively the most efficient for the course. The length and width of the chassis is 2500x1000mm. We decided to use the maximum length of the soapbox, as our driver needs ample leg room.

We also needed it to be able to support the overall height of 1531mm to meet the roll bar criteria (Castle Soap Box Derby, 2023) the 'roll bar needed to be 35mm above the driver's helmet'.

The chassis contains support bars both underneath the driver and on the backboard behind the seat to ensure that the soap box is sturdy and will protect the driver if an accident were to occur.

For our steering system, we opted for two-wheel drive as four-wheel drive would be over complicated and heavier.

Calculations and analytics

This section focuses on the numerical aspects of the soapbox and how the soapbox should perform based on the data from the equations used. The values of mass and pushing force are assumed using averages found online to be able to calculate other values such as velocity. The average mass of a soapbox racer is 200-240lbs. (https://cms9files.revize.com/athenstn/P&R%20Programs/Sports/SBD/Soap%20Box%20Derby%20Expectations.pdf) The value of 103.47kg is an assumed value between the values found online to use for calculations.

Mass	~103.47kg
Length	2500mm
Width (left to right)	1000mm (without wheels)
Height	1531mm
Pushing Force	800 N (400 N per person)
Wheel Diameter	519mm
Wheel Radius	259.5mm
Weight	1015.04N (103.47kg x 9.81)
R (reaction force)	Mg

Figure 2-1 Table showing all known information about the soapbox racer (Rhodri Jones, 2024)

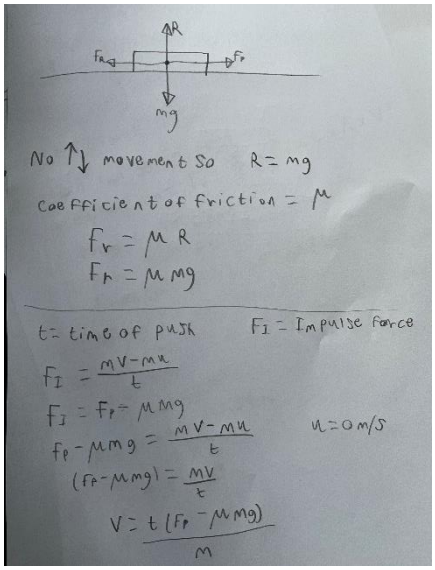


Figure 2-2 Handwritten workings out of equations. (Rhodri Jones, 2024)

To work out the maximum velocity the soapbox would travel on a flat surface knowing the mass, pushing force, pushing time and coefficient of friction between the tires and the surface. According to the University of Florida (No date or author) and engineersedge.com (2024) the coefficient of friction between rubber tires and concrete is μ = 0.6

R = mxg
R = 103.47x9.81
R = 1,015.0407 N

Friction = μxR
Friction = 0.6 x 1,015.0407
Friction = 609.0244 N

If pushing time = 3 seconds, then the pushing force would be F_p and initial force (F_i) would be calculated using $F_i = \frac{mv-mu}{t}$

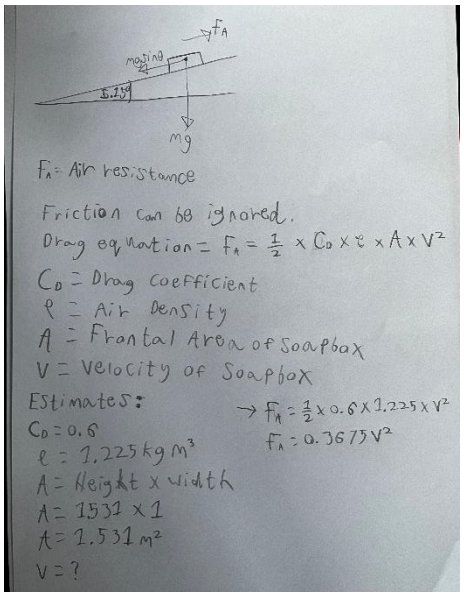
$F_i = (F_p – \mu mv)$

$F_p - \mu mv = \frac{mv-mu}{t}$
u (initial velocity) = 0 m/s,
so $F_p - \mu mv = \frac{mv}{t}$
$v = \frac{t\,(Fp - \mu mg)}{m}$
so $v = \frac{3\,(900 - 0.6 \times 103.47 \times 9.81)}{103.47}$
maximum velocity on a straight concrete surface = 8.437 m/s

To get the acceleration of the soapbox during the pushing period, $a = \frac{v-u}{t}$

$a = \frac{8.437-0}{3}$

$a = 2.812\ m/s^2$



Maximum downhill velocity calculated:

The average downhill angle in a soapbox race is between 4.6º-5.7º (ChatGPT 3.5 prompt, 2024.) The average of these numbers, 5.15º, will be used to calculate the average angle of the hill.

Friction can be ignored since the wheels roll on the surface and the friction between the rubber tires and concrete road can be considered negligible.

C_D is the drag coefficient.

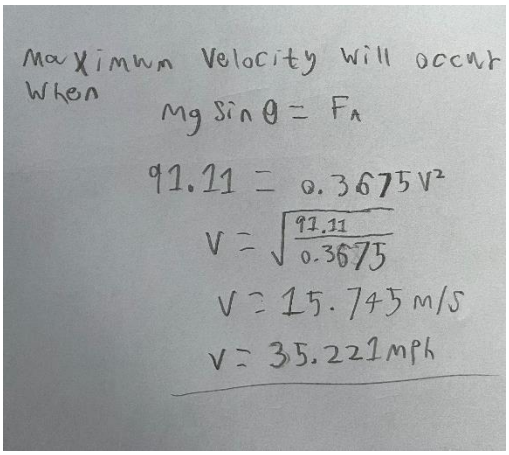
Figure 2-3 Handwritten workings out of equations. (Rhodri Jones, 2024)

We can assume that ρ (air density) is about 1.225 kg/m^3 due to average air density being 1.225 kg/m^3 according to Rowland Stull. (UBC ATSC 113 - Weather for Sailing, Flying & Snow Sports, 2019 by Roland Stull.)

A being the area of the front side of the soapbox racer is calculated using height x width.

A = 1.531m x 1m = 1.531m^2

By using the drag equation:



$F_A = 0.5 \times C_D \times \rho \times A \times v^2$ (ChatGPT 4, verified using OmniCalculator, Miłosz Panfil, 2024)

$F_A = 0.3675v^2$

Maximum velocity occurs when $mg\sin\Theta = F_A$

$mg\sin\Theta = 103.47 \times 9.81 \times \sin 5.15^\circ$

$mg\sin\Theta = 91.11$

$91.11 = 0.3675v^2$

Figure 2-4 Handwritten workings out of equations. (Rhodri Jones, 2024)

$V^2 = \frac{91.11}{0.3675}$ v = 15.745 m/s v = 35.221 mph

Evaluation

Based on the outcome of the Soap box design that we produced in SolidWorks some sections can be improved upon.

Some sections left a lot to be desired, our relative infancy in utilizing CAD software was a limiting factor. In a more refined attempt, we believe we could improve on the design.

One limitation that came to mind was our lack of knowledge with the implementation of diagonal planes. We believe our approach at designing the rear wheels would be different with a better understanding.

We also had some difficulty making sleek, aerodynamic frames. Once again, understanding the software better would have allowed for a more polished look, and better aerodynamics.

Conclusion

Overall, we are pleased with our results. The materials we chose seem ideal, considering the criteria and circumstances. Steel is not only cheap and readily available, but its heaviness relative to other metals is ideal to prevent rolling.

We are quite happy with our CAD design, as mentioned, more experience with the software would have resulted in a better design, but we are content with this one.

We like the aesthetics of the design; its simple shapes would make manufacturing less complicated.

Ultimately, we believe we went with the appropriate design philosophy.

References

Issac Alaska, 2015. Available at : CAD Model a Tire in SolidWorks : 11 Steps - Instructables (Accessed 26/04/24)

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