

University of Wales Trinity Saint David

Wales Institute of Science & Art



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

***Designing a Gravity Racer in Compliance with the
Rules and Regulations of the Richards Castle
Soap Box Derby***

Integrating Project ACHA4008

Callum Carter-Davies, Jay Delancy, Joao Ferreira,
Rhien Williams, Elliot Woodhouse

Student ID: 2008376, 2005231, 1902427, 1901571, 1908452

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1. Introduction

This report will outline the design of the gravity racer using CAD software, present calculations for forces that the racer and separate components will endure whilst being driven. The suitability of the design of the racer will also be commented on and how certain aspects of the racer could be improved upon.

2. CAD Design

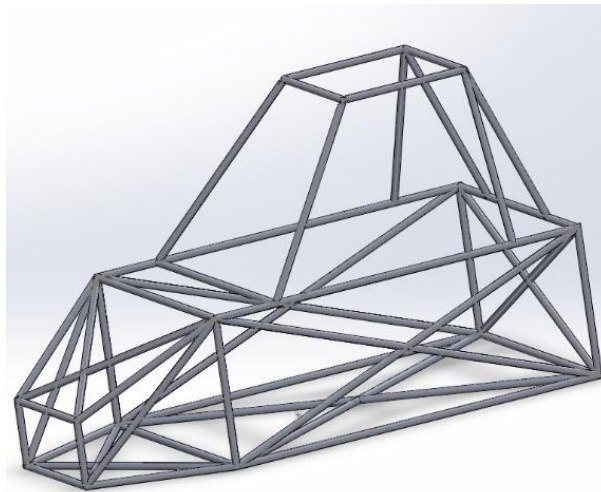


Figure 1 - Gravity Racer Chassis

Figure 1 shows the design for the chassis of the gravity racer. Inspiration for this design was taken from the Formula X Autocross series. This is due to the roll cage being incorporated into the chassis which will protect the driver from serious injury in the case of a roll. The structural rigidity of this specific design is also one reason it was chosen. In the case of a crash, the crossbars integrated into the chassis will help strengthen the body and protect the driver.

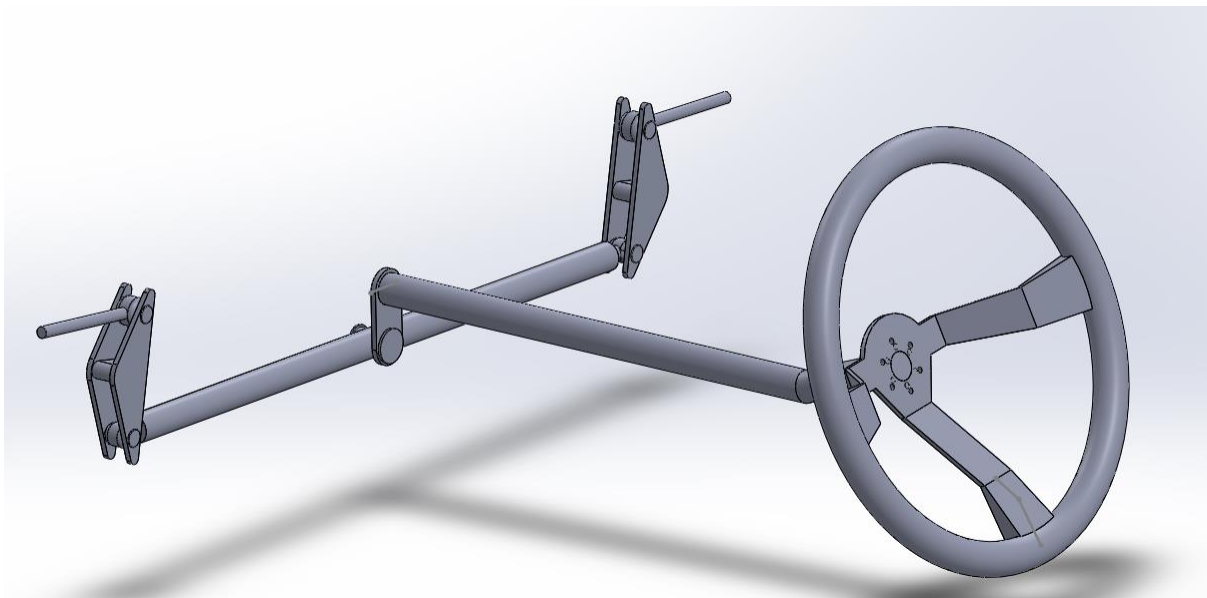


Figure 2 - Steering Assembly



Figure 3 - Wheel Assembly

Figure 3 shows the wheel assembly of the gravity racer. This includes the wheel itself, the tyre, the brake disk, the axle and the wheel nut. The Raleigh Trubuild 18x1.75 wheels were chosen due to their low cost, being made from aluminium providing them with strength whilst also being lightweight (Rutland Cycling, 2021) and also not being too large in diameter to cause them to bend and buckle under heavy cornering forces like larger bicycle wheels (ScottishCarties, 2013).

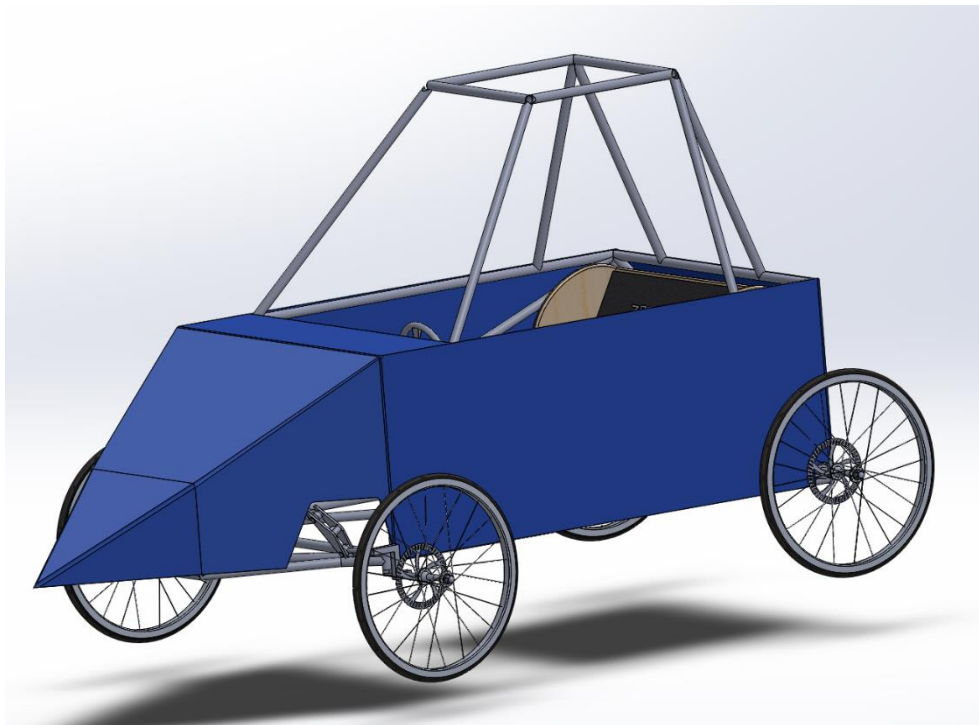


Figure 4 - Gravity Racer Fully Assembled

3. Analytical Work

The mass of the soapbox was calculated by working out the sum of all the combined parts of the gravity racer plus the mass of the driver.

Due to the gradient of the course changing frequently, multiple gradients were assumed and used to calculate the force of the gravity racer at these gradients.

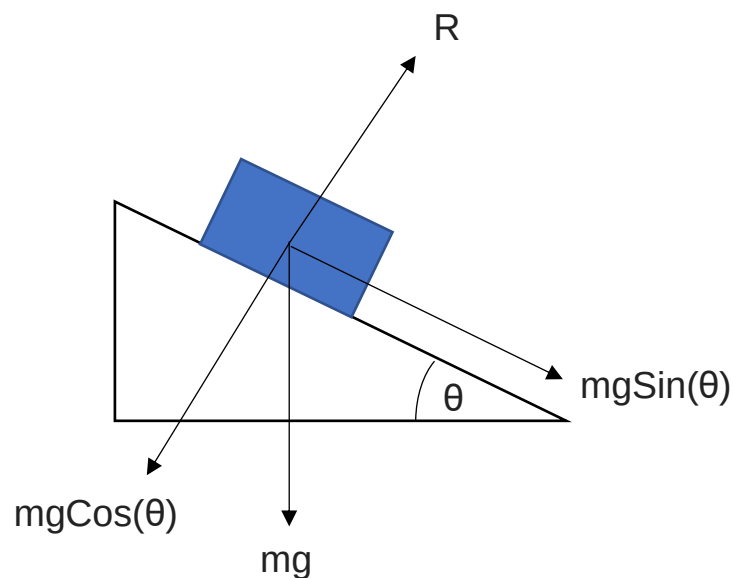


Figure 5 - Forces Diagram of Gravity Racer on Slope

Mass of gravity racer including driver (m) = 151.86kg

Gravity (g) = 9.81ms^{-2}

θ = Angle of slope

a = acceleration of the gravity racer

The equation $mg\sin(\theta)$ was used to calculate the force of the gravity racer going down the slope.

From here, acceleration was calculated using the equation $F = ma$, where F = force. This equation was rearranged to give $a = F/m$.

Table 1 - Force and Acceleration of Gravity Racer at Different Gradients

Decline Gradient (°)	Force of Soapbox Downhill (N)	Acceleration (ms ⁻²)
5	129.8399714	0.854997836
10	258.6917823	1.703488623
15	385.5747925	2.539014832
20	509.5233457	3.355217606
25	629.5941185	4.145885148
30	744.8733	4.905
35	854.4835459	5.626784841
40	957.5906561	6.305746451
45	1053.409923	6.936717523

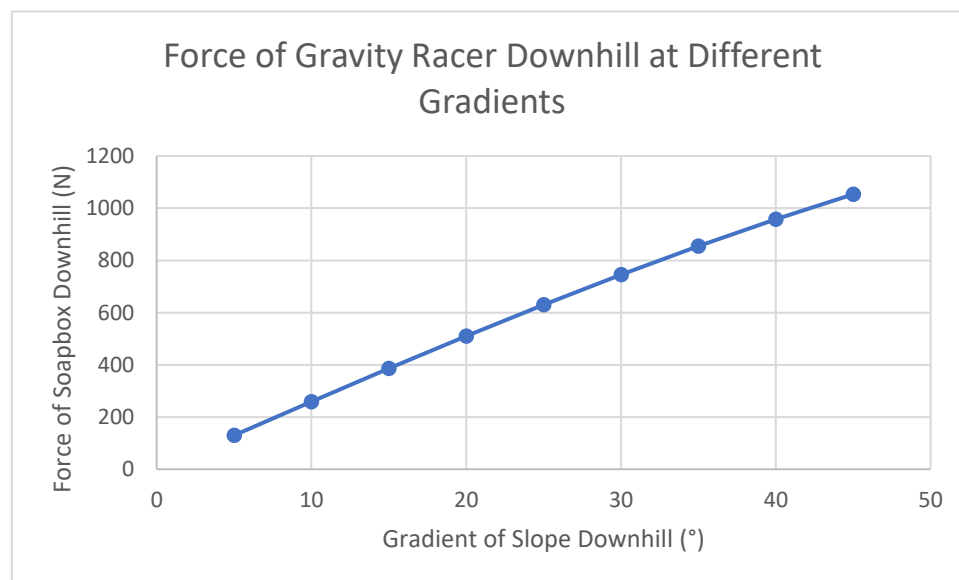


Figure 6 – Force of Gravity Racer Downhill at Different Gradients

Due to not being able to build and test the gravity racer, friction and air resistance had to be assumed to be zero. This is whilst in real world application there would be resistive forces which would therefore result in the gravity racer not accelerating as quickly.

It states on the Richard's Castle Soap Box Derby website that the gravity racers can expect to achieve speeds of up to 40mph (17.8816 ms⁻¹) on the steeper slopes of the course (Richard's Castle Soap Box Derby, 2020).

This information was then used to calculate the angular velocity of the wheels using the equation linear velocity = radius x angular velocity ($v=r*\omega$).

Radius of wheel = 9 inches = 0.2286m (Rutland Cycling, 2021)

$$\omega = v/r$$

$$\omega = 17.8816/0.2286$$

$$\omega = 78.222 \text{ rad/s}$$

The mass moment of inertia was then calculated using the equation $k^2=d^2/8$

$$k^2 = 0.4572^2/8$$

$$k^2 = 0.02612898 \text{ kg m}^2$$

Inertia was then calculated using the mass of the wheels and all other moving components on the wheels.

$$I = m \times k^2$$

$$I = 1.15 \times 0.02612898$$

$$I = 0.0300488327 \text{ kg m}^2$$

Then the kinetic energy of the wheels was calculated using the equation:

$$KE = \frac{1}{2} I \omega^2$$

$$KE = \frac{1}{2} * 0.0300488327 * 78.222^2$$

$$KE = 91.929 \text{ J to 3 decimal places.}$$

4. Evaluation

The group has worked well to take one design from the first assignment and carry it over to further design & alter the gravity racer to fit the for Richard's Castle Soap Box Derby. It was a challenge for the group to design certain parts of the gravity racer in Solidworks, for example the spokes on the wheels. Assembling the parts of the gravity racer was also a challenge at times due to parts being awkward to align properly, however they were eventually assembled properly.

The gravity racer has been designed to suit the soapbox derby to maximise safety for the driver whilst also not hindering performance as much as possible by integrating chassis design ideas from Formula X Autocross Series. The gravity racer also complies with all regulations set by Richard's Castle Soap Box Derby by following all rules to do with the chassis, roll bars, steering and falling within the size regulations of the entire gravity racer.

To improve upon the design of the gravity racer, suspension could have been added. This would have resulted in the gravity racer being able to absorb any energy caused by uneven surfaces in the track, resulting in the gravity racer losing momentum and being faster down the track whilst also making the ride comfier for the driver. Having suspension would also cause the car to have more grip since the tyres would be in contact with the surface of the road more often over uneven ground.

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