Embodiment Design Report
MECH 2412 Mini Design Project 1

LAB 03 Group 4
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Due Date: 03/12/2024

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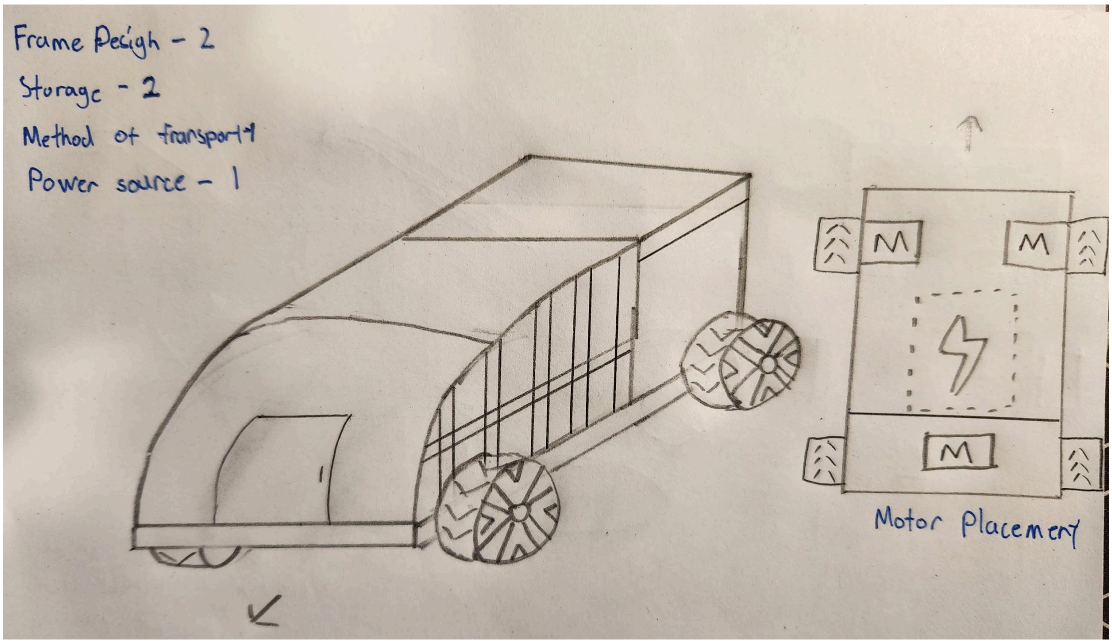
1) Conceptual Design

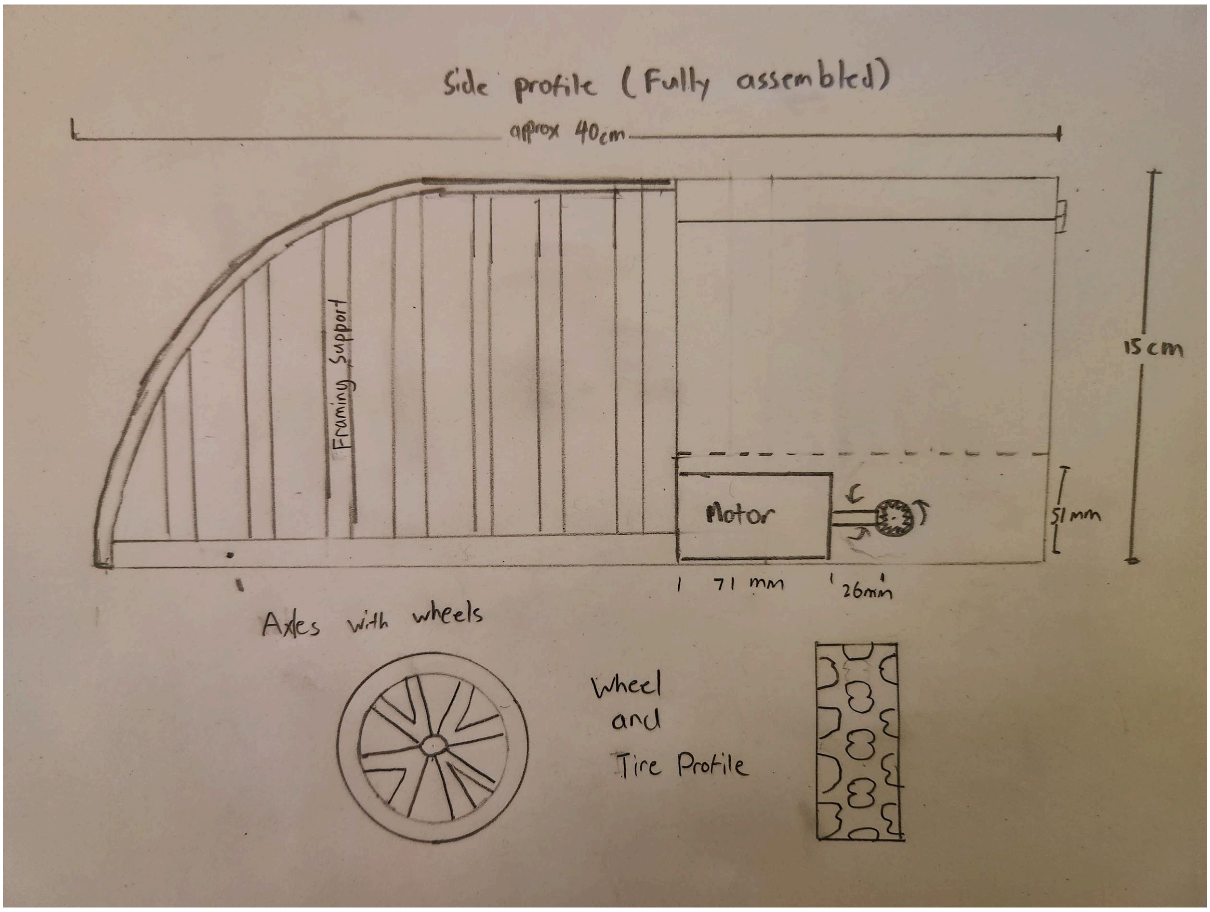
Since the end of the pandemic, hiking has become a very popular form of exercise. People are heading to parks and mountains in the GTA to get fresh air and cardio. This rise in hikers has also increased the number of injuries and missing people reports. The provincial government of Ontario has been sending search and rescue teams however this is proving to be ineffective and time consuming. They can only send out so many teams before they lose too much manpower. There is also concern over search teams safety and the costs of supplies. For this reason, the province has hired an engineering firm to develop a technology that will help the search and rescue locate missing people more easily. The engineering firm in turn hired students at York University to design and create a search and rescue vehicle with a few guidelines such as having collision avoidance and being controlled by an arduino board.

The design must also be to withstand obstacles on its search such as falling down. It must also transport important medical and survival supplies to help the missing or injured people survive until they can be extracted. Our team has chosen the below design as our search and rescue vehicle's final design. The storage will be placed at the back of the vehicle and be detachable. The vehicle must be able to support the weight of supplies such as food and medkits. It will have a curved front piece to allow for better aerodynamics in windy conditions. It uses sensors to detect obstacles and avoid them as well as a GPS tracking system. The goal of our vehicle is to search and locate missing people through different terrains efficiently and to help save lives.



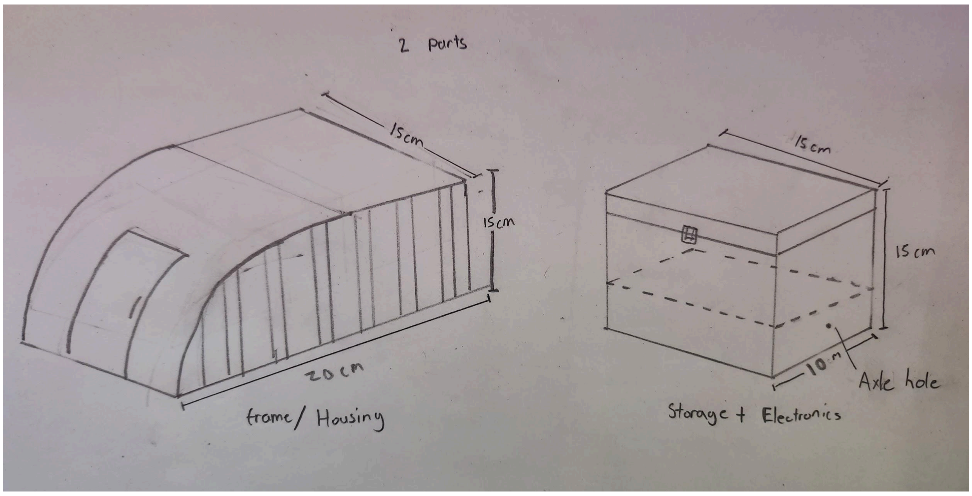
Our Original Design from the Conceptual Design Phase.

2.1) Conceptual Design Sketch and Preliminary Layout:

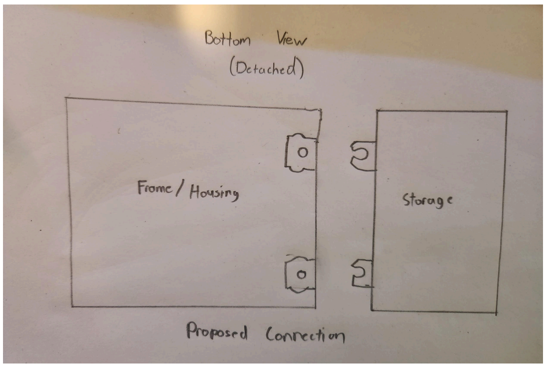


From these preliminary sketches and designs, the shape and layout remains mostly unchanged due to its simplicity. The frontal area's angles come a bit steeper but this was designed in a way that would make it more rigid in nature. Making it more resilient to buckling will ensure safety of the passenger and the reusability of the vehicle. As stated before most if not all of the electronics will be located under the storage container. This was done this way to make more room for the passenger but to also have a safer weight distribution when traversing down slopes and trails. However, it is not just boxed in there with no access points as there will be an access panel from under the proposed storage area (The dotted line). This will make sure that maintenance is conducted after the vehicle is cleaned out. The storage container is also equipped with an easy to open latch for the victims that have little to no energy left.

The axle placement is not a mistake either. As mentioned before, it is to allow it to easily traverse along slopes at the comfort of the passenger without fear of toppling over. The wheel design is mostly the same, but we intend on using rubber tires to provide enough traction to move along not only smooth surfaces but also rough terrain.



Due to ease of access, we plan to 3d print most of our components. These would include parts like the frame/housing, the storage container, the connectors that would attach the two aforementioned parts, and a few bindings to keep things like the motor in place as it operates. The two main components will also be printed with a way for them to attach and detach from itself to fit within the constraints of the project outline. This system is almost like the buckles you see on helmets and such.



There were a few parts however, we thought were better off not being made from 3D-printed PLA like the wheel rims and the axles. Due to those parts taking most of the force inflicted from the ground, they would have to be sturdy, just like an actual automobile. This is why we decided to try and make the wheel rims through the machine shop and buy the axles.

One other thing we plan on buying for just the “shell” of the build, which doesn’t include the inner workings of the kart, were rubber tires. These are proposed to be sourced from a hobby shop or just from a retailer that specialises in remote control buggies. This decision came from 2 factors. The first being that if it was printed from PLA, it would slip off inclines. The second is due to our limitations as designers. The complexity of designing tires is a field that none of our group members are familiar with. Buying already made ones ensures their quality and performance.

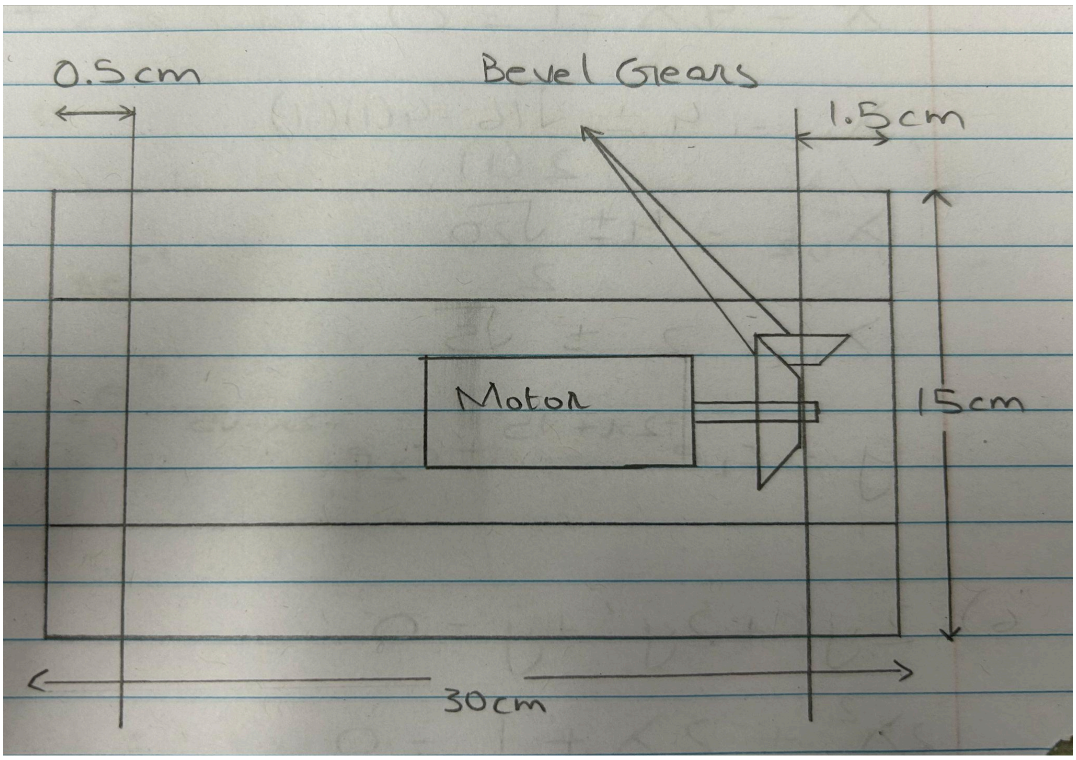
This vehicle has a RWD design, which means more weight has to be put in front to make sure it doesn't tip over. To counter this dilemma, we designed the car's housing to be longer in front. This coupled with the fact that passengers also sit in the front and will bring some of the load from the storage box to the front with them as they get in. For our planned prototype demonstration, we plan to put most, if not all the weight in that front housing.

2.2) Design Calculations

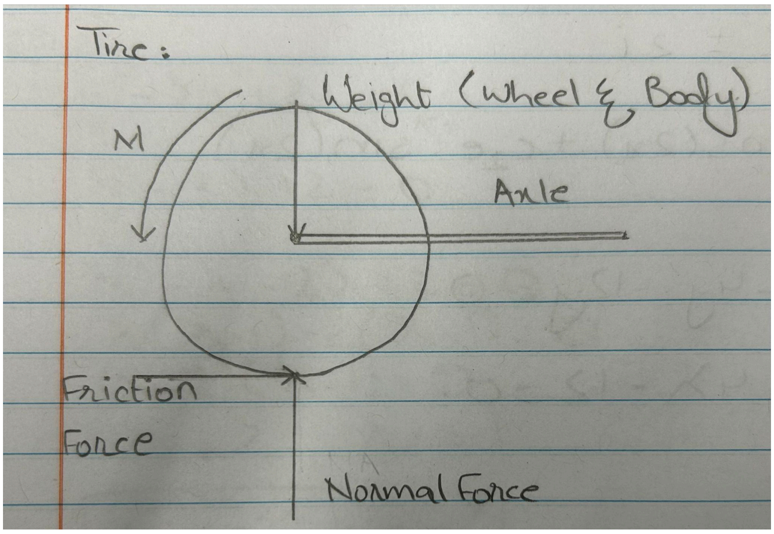
Strength Calculations:

Material	**Yield Strength (MPa)**	**Young's Modulus (GPa)**
Fiberboard Sheet	24.0	4.00
Low-carbon steel rods	180	213
Stainless steel hex screws and hex nuts	671	0.196
Rubber Bands	27.6	0.00127

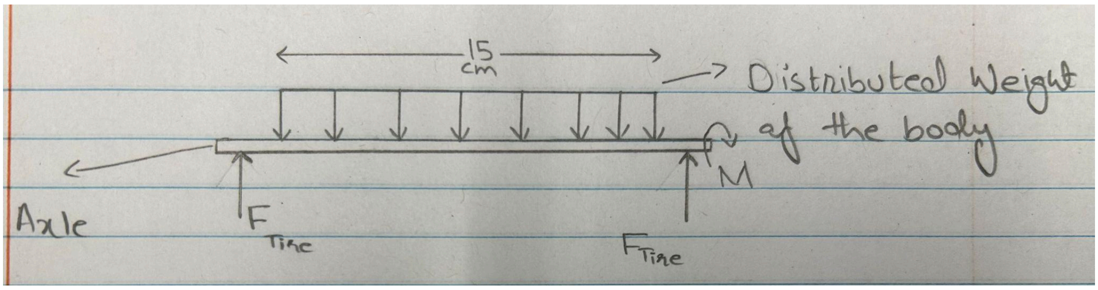
Chassis FBD:



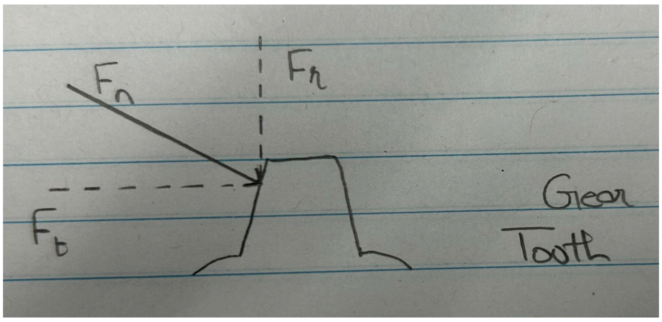
Tires FBD:

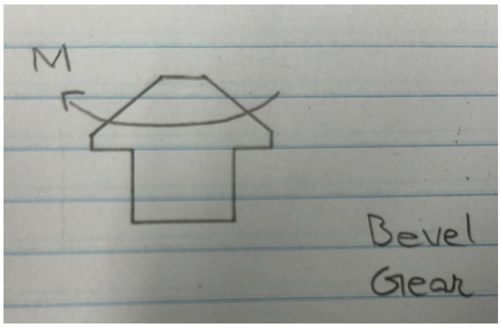


Force and Moment on Axle FBD:

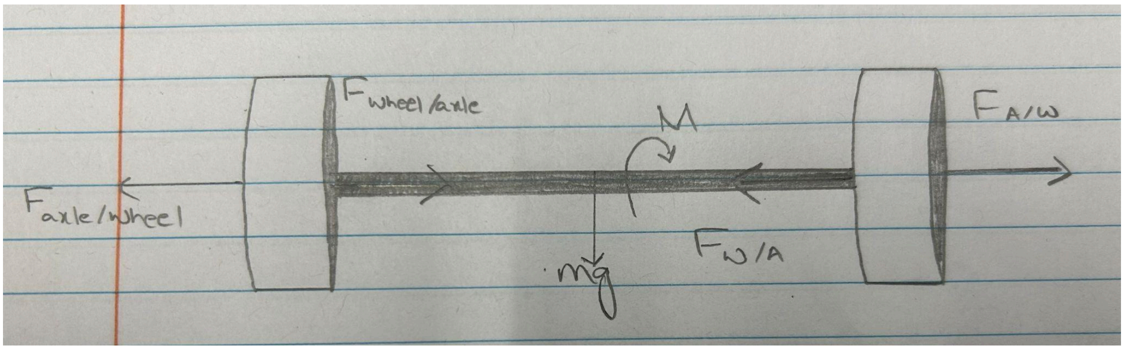


Gear Moment and Force FBD:

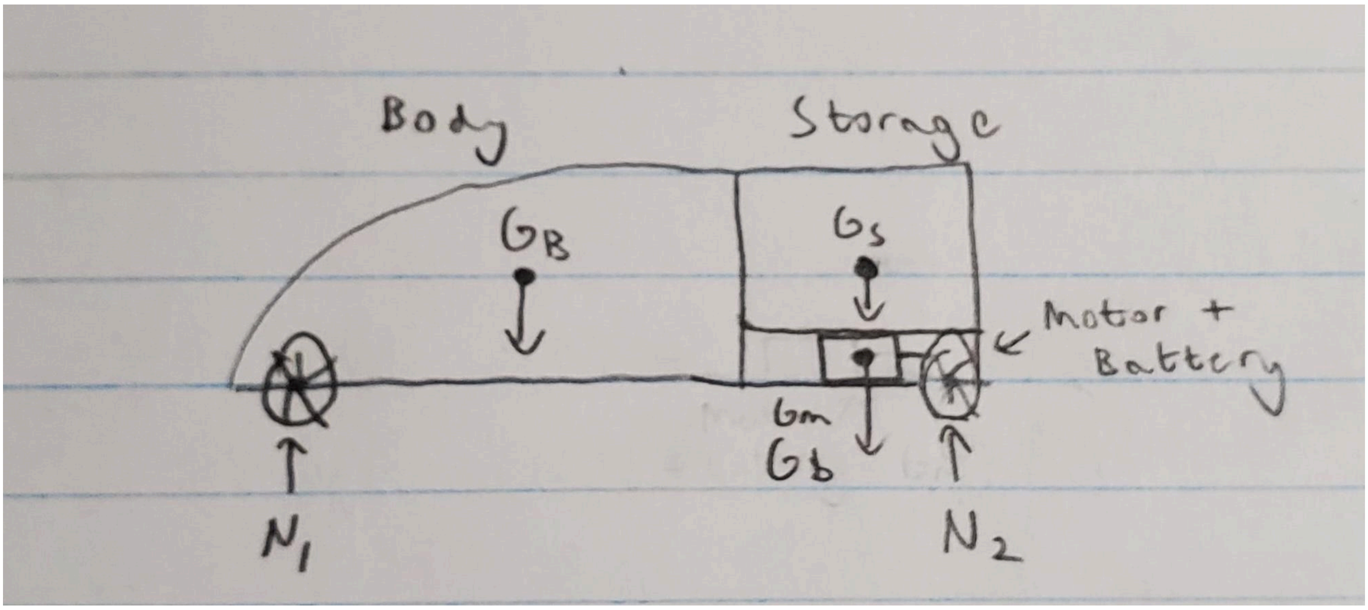




Reaction Forces and Moment on Axle and Wheel:

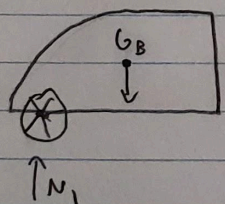


Normal Forces acting on the Wheels:



- $m_{body} = 0.1\,kg$ • $m_{storage} = 0.3\,kg$ • $m_{battery} = 0.034\,kg$ • $m_{motor} = 0.544\,kg$
- The weight of electronics are very small so they are ignored

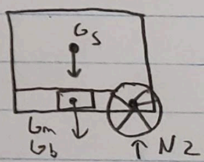
Front



$+\uparrow \sum F_z = 0 = N_1 - G_B \Rightarrow N_1 = G_B$

$N_1 = m_{body}\,g = (0.1\,kg)(9.81\,\frac{m}{s^2}) = 0.981\,N$

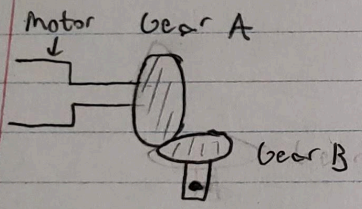
Back



$+\uparrow \sum F_z = 0 = N_2 - G_s - G_m - G_b \Rightarrow N_2 = G_s + G_m + G_b$

$N_2 = m_s g + m_m g + m_b g = (0.3\,kg)(9.81\,\frac{m}{s^2}) + (0.544\,kg)(9.81\,\frac{m}{s^2}) + (0.034\,kg)(9.81\,\frac{m}{s^2}) = 8.61\,N$

How Fast gears will be moving:



- Gear A has 40 teeth
- Gear B has 20 teeth

Gear Ratio $= \frac{40}{20} = 2$

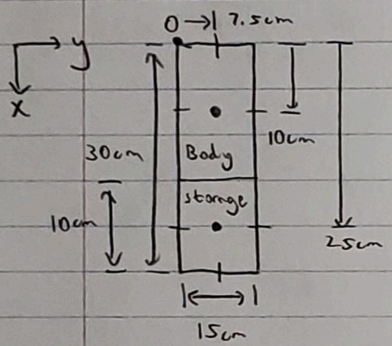
- Motor has a 3500 rpm

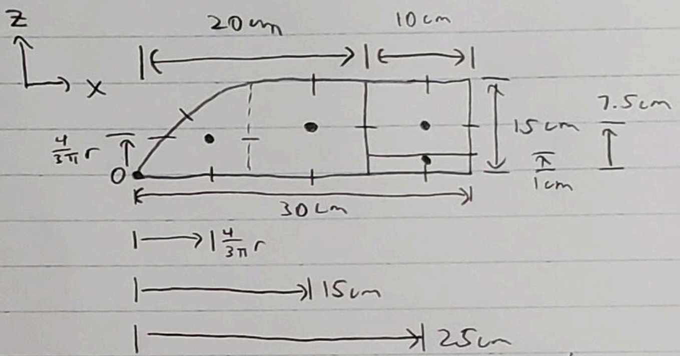
$$\omega_A = \frac{2\pi(\text{rpm})}{60} = \frac{2\pi(3500)}{60} = 366.52 \text{ rad/s}$$

$$\omega_B = GR(\omega_A) = 2(366.52) = 733.04 \text{ rad/s}$$

Center of Mass:

- Assume battery and Motor have same center of mass in x and y as storage
- $m_{body} = 0.1$ kg
- $m_{storage} = 0.3$ kg
- $m_{battery} = 0.034$ kg
- $m_{motor} = 0.544$ kg





$$x_{cm} = \frac{\Sigma M x}{\Sigma M} = \frac{\left(0.05 \times \frac{4}{3\pi}[15]\right) + (0.05 \times 15) + (0.3 \times 25) + (0.544 \times 25) + (0.034 \times 25)}{0.05 + 0.05 + 0.3 + 0.544 + 0.034}$$

$x_{cm} = 23.54$ cm

$$y_{cm} = \frac{\Sigma M_y}{\Sigma M} = \frac{(0.1 \times 7.5) + (0.3 \times 7.5) + (0.544 \times 7.5) + (0.034 \times 7.5)}{0.1 + 0.3 + 0.544 + 0.034} = 7.5 \text{ cm}$$

$$z_{cm} = \frac{\Sigma M z}{\Sigma M} = \frac{\left(0.05 \times \frac{4}{3\pi}[15]\right) + (0.05 \times 7.5) + (0.3 \times 7.5) + (0.544 \times 1) + (0.034 \times 1)}{0.05 + 0.05 + 0.3 + 0.544 + 0.034}$$

$z_{cm} = 3.6$ cm

- Center of Mass: $(23.54, 7.5, 3.6)$

Axle:

Assuming the weight of the axle is 200g with a diameter of 5mm and covered length of 4cm. 2 wheels, each of weight 100g. So,
Stress = F/A
Stress = ((0.2+0.1+0.1) x 9.81) / (0.005x0.04)
Stress = 19,620 KPa
Stress = **19.62 MPa**, which is less than the yield strength

Gears:

There are going to be 2 gears, low and high. 1 gear is attached to the axle and there is going to be a choice between 2 gears on the Motor. The ratio between the gears on the motor and on the axle is going to be **1:1** and **1.5:1**. Where 1.5:1 is the high gear.
Low gear is going to have an rpm of **3,500** and high is going to have an rpm of **5,250**.

Wheels:

The whole weight of the vehicle is going to be around 1.5 - 2 kg and with additional capacity of 1 - 1.5 kg. There are 4 tires so the load is going to be divided between them. A wheel is 2 cm thick with a diameter of 9cm

Stress = (3x9.81) / (0.02x0.09)
Stress = 16,350 KPa
Stress = **16.35MPa**

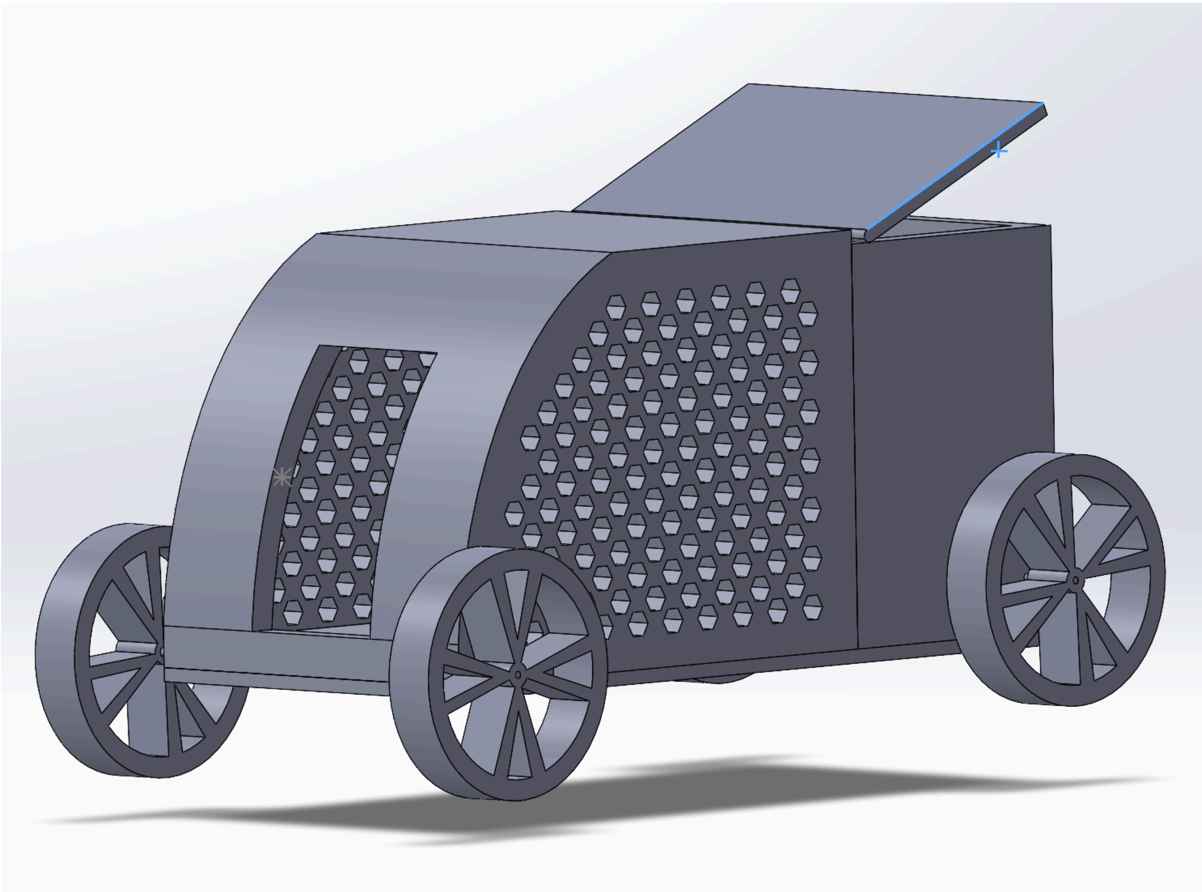
Testing Procedures:

To ensure that our vehicle is able to function as intended we will be conducting multiple tests on our prototypes. We will test the durability of the vehicle's exterior by placing objects such as rocks or sticks on the car. It must be able to withstand the force of an object weighing at least 3-4 kg.

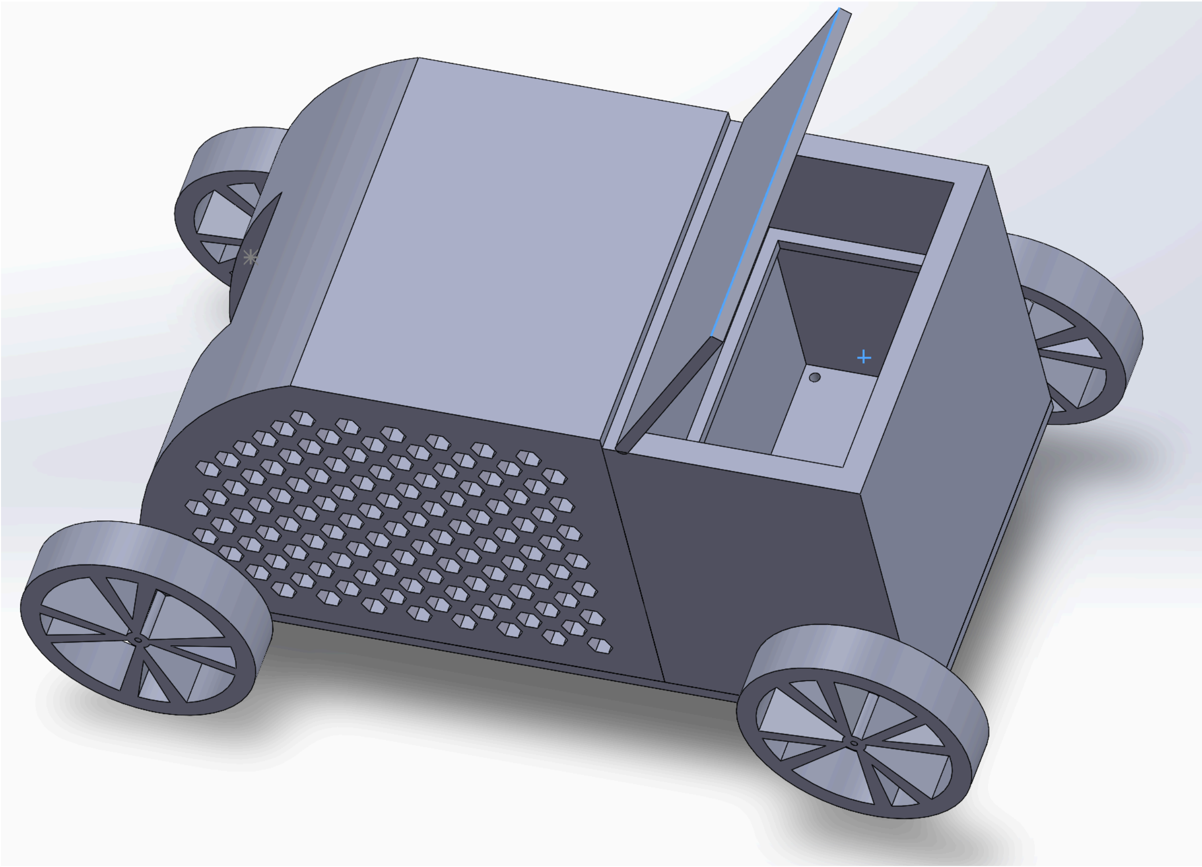
The electrical and motorary components must remain safe without moving or falling. We will test this by shaking the vehicle and driving it. We will also conduct drop tests on the car to ensure the wheels and axles can withstand the impact. The maximum height it will be tested at is around 1 metre. The vehicle will be driven over multiple different types of terrains to ensure it can manoeuvre efficiently. It will go through rocks, grass, and dirt.

Another test will be to ensure that the back half of the vehicle containing the storage box does not detach or open while it is moving. To test this we will apply force on the back section from multiple directions. We will also drive the car with a weight tied to the back to ensure it remains intact and this will also test how much weight the vehicle can pull. It must be able to carry the required supplies in the storage and possible extra items that the person possesses. To test the storage box we will drop it from different heights and forcefully try to pry it open. The box must not drop these essential items and should not be opened by animals.

2.3) Detailed (Definitive) Layout

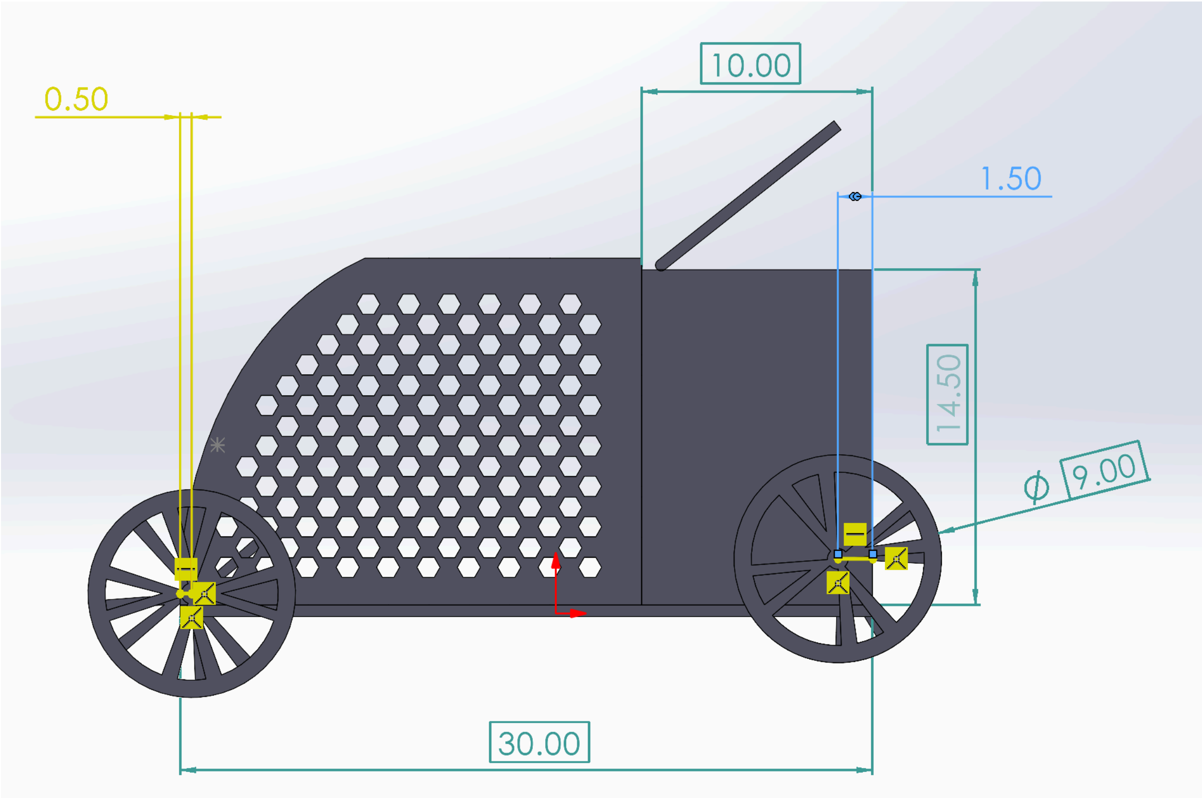


Caption 2.3.1: Although the definitive layout shown above appears to have no door, that is not a design choice. The door was removed to be able to display the inside. The door is intended to open like a ramp to allow tired passengers ease of access.

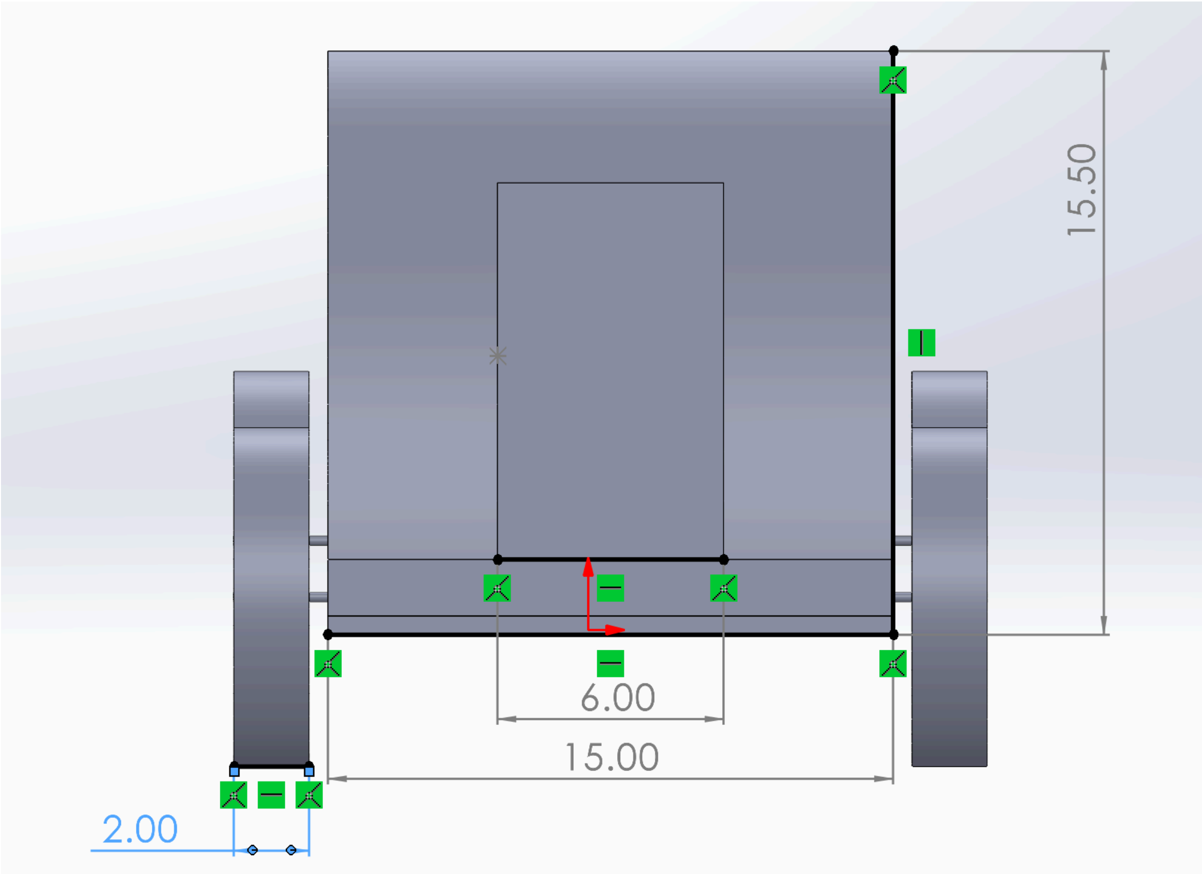


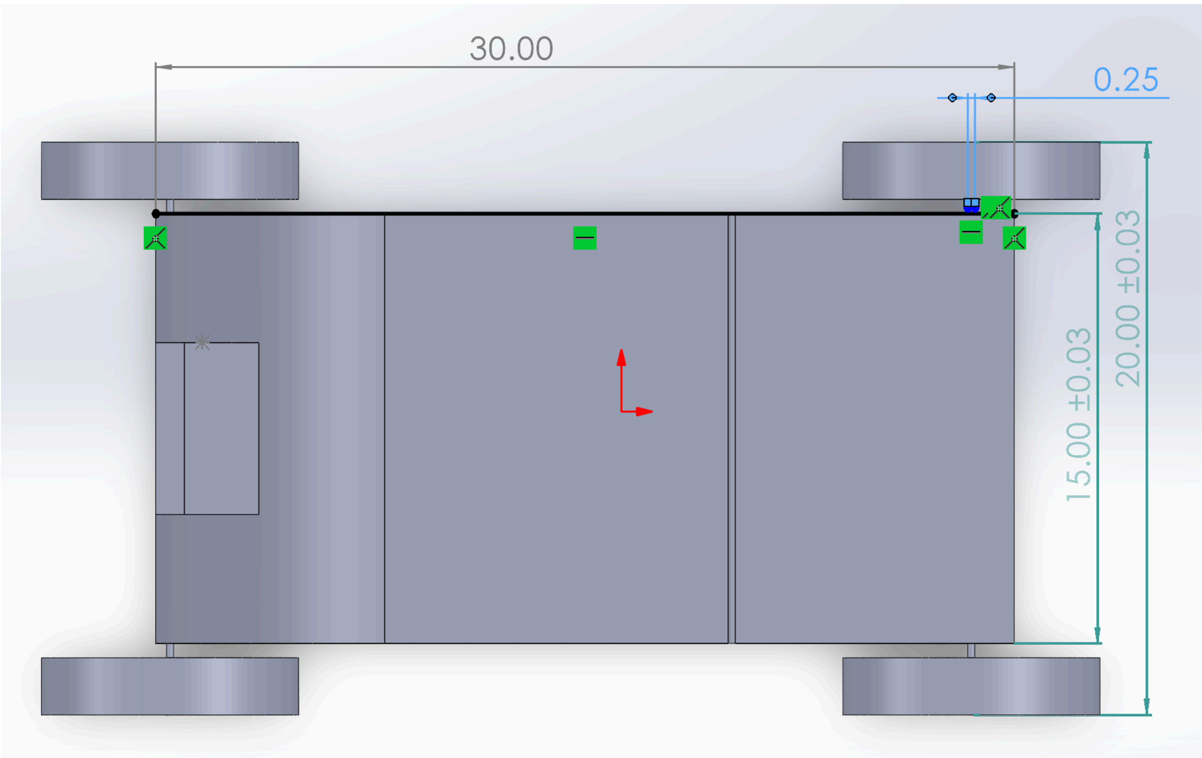
Caption 2.3.2: Trimetric view of the vehicle which shows the interior of the storage compartment where the motor, gearbox and other equipment will be stored. Notice that there is a lip to catch a board onto which would become the access panel of the mechanics. There are also pre-made holes to easily drill the box onto the fibre board.

Caption 2.3.3: The framing of the housing was ultimately changed from the conceptual design due 3 factors. The first being the safety of the passenger. The initial design's bars were large enough to stick an arm out of which is very dangerous especially in a forest or the mountains. The second is structural integrity. Nature already provides a strong structure in the form of a honeycomb, so we followed that design philosophy. Third would be weight reduction.



Caption 2.3.4: Side view of the vehicle to show the dimensions which include the vehicle length and height, tire diameter, compartment length and depth as well as the distance of the axle from the outside of the frame.


15.50
6.00
15.00
2.00


30.00
0.25
15.00 ±0.03
20.00 ±0.03

2.4) Expected Performance

With our design calculations and detailed layout we can confidently predict the performance of our design. Our expected performance includes the behaviour, capabilities and outcomes of our design project concerning our objectives and requirements.

Behaviour:

The behaviour of our design refers to how it will react in its intended environment, Our vehicle is designed to be able to traverse off-road terrain. Based on our detailed layout, our compact design (30cm x 15cm x 15.50cm) and large tires (9.00cm diameter) will allow it to navigate through uneven terrain. The placement of our motor near the center and bottom of the body will even the weight distribution and give it a lower center of mass:(23.54cm, 7.5cm, 3.6cm) improving its stability. Aswell based on our calculations our motor will be able to supply the necessary force to move the vehicle on inclined surfaces and the materials used will be able to withstand any forces applied.

Capabilities:

The capabilities of our design refer to the functions of the design and how effectively it completes them. Our design must be able to safely and comfortably transport passengers, our design includes a 10.00cm x 15.00cm x 14.50cm storage compartment to be able to carry any medical supplies and fit the motor. Our design also includes a compartment for the passenger that is 20.00cm x 15.00cm x 14.50cm. Our design must also have the capability to withstand harsh terrain so we use durable materials for our chassis like low-carbon steel rods and stainless steel hex screws and nuts with higher yield strength and test that it can withstand forces of 3-4kg without internal components being damaged.

Outcomes:

Our outcome should be the safe and efficient transport of a person. Based on the behaviour and the capabilities of our design it should be able to safely transport a passenger while navigating through off-road terrain, as well as meet our requirements of being modular with detachable storage from the frame, with optimized space allocated for everything.

2.5) Bill of Materials (BOM)

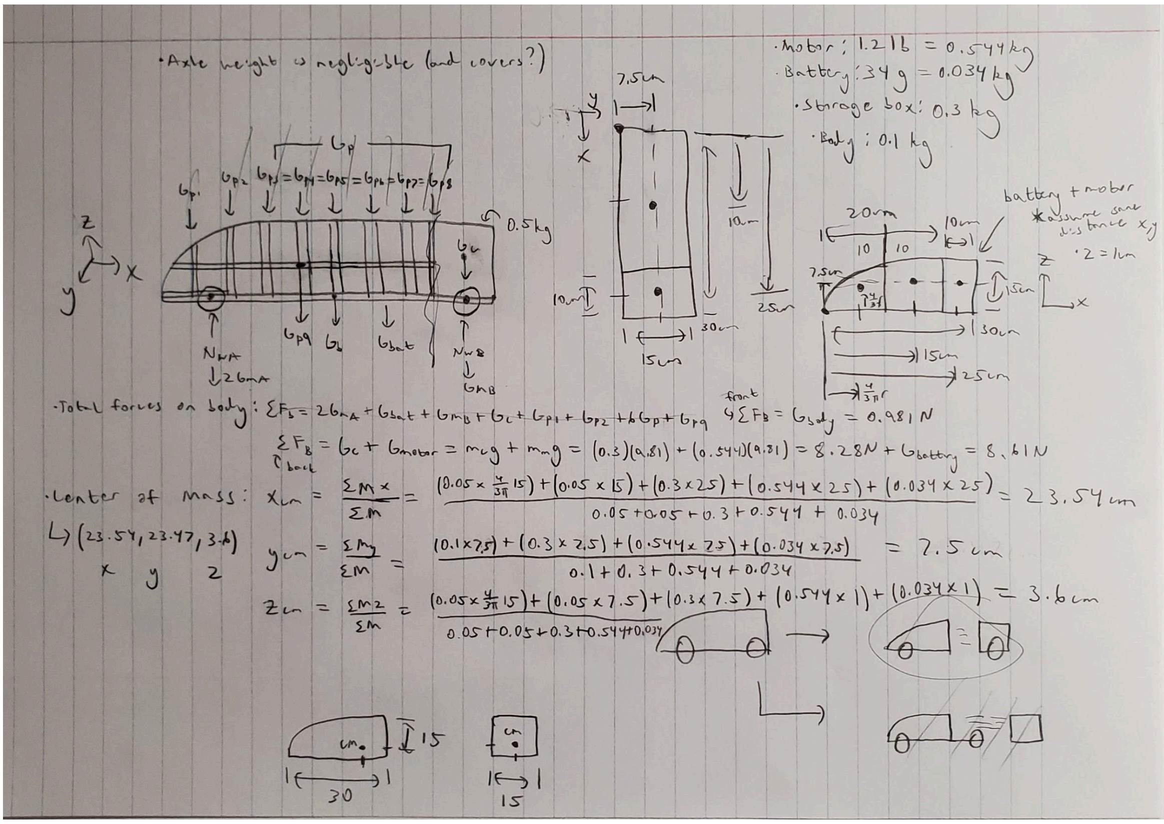
Item	Description	Supplier	Part #	Link to Store	Quantity	Cost
1	XD3420 Dual ball bearing DC 12V Motor	York University			1	$0
2	1:2 Bevel Gear 1.5M 20 Teeth 40 Teeth Bore 10 mm Gear 90 Degrees Meshing Angle Steel Gears 45#	AliExpress	1.5M 20 Teeth 40 Teeth	https://www.aliexpress.com/item/1005005480124559.html?src=google&aff_fcid=40eb56e9877848bfaee98d0ee1d5307e-1710292401819-05639-UneMJZVf&aff_fsk=UneMJZVf&aff_platform=aaf&sk=UneMJZVf&aff_trace_key=40eb56e9877848bfaee98d0ee1d5307e-1710292401819-05639-UneMJZVf&terminal_id=8a39864976164c3c98af636f8ca19c9b&afSmartRedirect=y	1	$7.11
3	9V Lithium Ion Battery	York University			1	$0
4	Low Carbon Steel Rod	York University			2	$0
5	Arduino Uno wifi-board	York University			1	$0
6	Obstacle Avoidance Module	York University			1	$0
7	IR Receiver	York University			1	$0
8	Remote Control Transmitter	York University			1	$0
9	LED’s	York University			1	$0
10	Battery Clip	York University			1	$0
11	1/10 RC Rock Crawler Racing Car Tire Tyre	Walmart	09041572600213	https://www.walmart.ca/en/ip/RXIRUCGD-Kids-Toys-Gifts-Sale-Clearance-110MM-1-9-Inch-Rim-Tyre-Wheel-Tire-For-1-10-RC-Rock-Crawler-SCX10-D90-TRX4/5CHWHGG0EIES?skuId=4OIYU86JDY06&offerId=3D3D2BADE4704B00861D968854B9B4D4	1	$13.26
12	Container	York			1	~$10

		University 3D Printing Services				
13	Exterior Body	York University 3D Printing Services			1	~$10

Appendix A: (Meeting Minutes)

Date	Meeting Length	Attendance	Items Discussed	Decisions Made	Tasks Assigned	Outcomes of Previous Work
2/25/2024	2 Hours	Everyone	Roles, Reviewed preliminary kart design	Design of Vehicle	Each Members role	Analysed previous students projects
3/3/2024	3 Hours	Everyone	Discussed Safety Features, What materials will be used for each part, Picked a final design	Bill of Materials, picked a final design	Assigned Team Members to finalise storage design	Picked our final design based off of analysis of previous student projects and discussion
3/11/2024	3 Hours	Everyone	Final Report/Presentation	Completed Report	Each Member got tasked with roles for the report and video	Created a final report and video based off of our final design chosen in our last meeting

Appendix B: (Hand Calculations)



• Axle weight is negligible (and covers?)

• Motor: 1.2 lb = 0.544 kg
• Battery: 34 g = 0.034 kg
• Storage box: 0.3 kg
• Body: 0.1 kg

battery + motor
*assume same distance x, y
• z = 1cm

• Total forces on body: $\Sigma F_b = 2G_{mA} + G_{bat} + G_{mB} + G_c + G_{p1} + G_{p2} + 6G_p + G_{p9}$ front ↳ $\Sigma F_B = G_{body} = 0.981\,N$

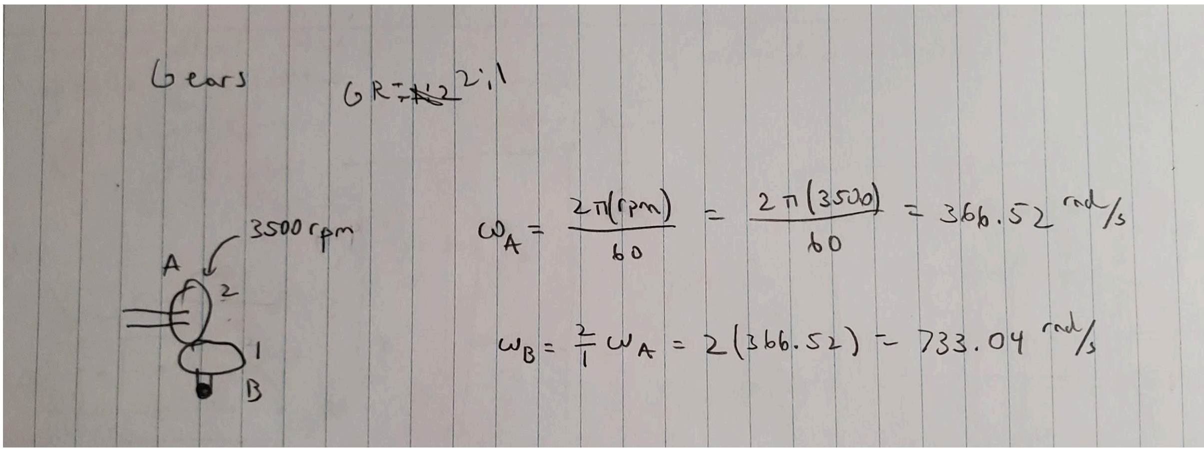
$\Sigma F_{B,\text{back}} = G_c + G_{motor} = m_c g + m_m g = (0.3)(9.81) + (0.544)(9.81) = 8.28N + G_{battery} = 8.61N$

• Center of mass: $x_{cm} = \dfrac{\Sigma m x}{\Sigma m} = \dfrac{(0.05 \times \frac{4}{3\pi}15) + (0.05 \times 15) + (0.3 \times 25) + (0.544 \times 25) + (0.034 \times 25)}{0.05 + 0.05 + 0.3 + 0.544 + 0.034} = 23.54\,cm$

↳ (23.54, 23.47, 3.6)
x y z

$y_{cm} = \dfrac{\Sigma m y}{\Sigma m} = \dfrac{(0.1 \times 7.5) + (0.3 \times 7.5) + (0.544 \times 7.5) + (0.034 \times 7.5)}{0.1 + 0.3 + 0.544 + 0.034} = 7.5\,cm$

$z_{cm} = \dfrac{\Sigma m z}{\Sigma m} = \dfrac{(0.05 \times \frac{4}{3\pi}15) + (0.05 \times 7.5) + (0.3 \times 7.5) + (0.544 \times 1) + (0.034 \times 1)}{0.05 + 0.05 + 0.3 + 0.544 + 0.034} = 3.6\,cm$



Gears GR = 2:1

$\omega_A = \dfrac{2\pi(rpm)}{60} = \dfrac{2\pi(3500)}{60} = 366.52\ rad/s$

$\omega_B = \dfrac{2}{1}\omega_A = 2(366.52) = 733.04\ rad/s$

Appendix C: (Design Logbooks)

Date	Progress
02/13/2024	- Obtained main components of for the build of the project - Familiarized ourselves with the components and decided how we planned to use each one - Decided what parts goes home with which group members for optimal attendance and specialisation
02/18/2024	- Beginning of a discussion of how to program the Arduino UNO - Dedicated two group members to handle the programming - Collaborated ideas to streamline the coding in case of sick group member
02/23/2024	- Held a group discussing to relearn how to use the hardware - Topics included how to use the breadboard, when to use resistors, how to operate a multimeter - Also discussed how we might produce the prototype - 3D printing and a bit of machining
02/28/2024	- Started discussion for the Embodiment Design Report - Decided how we are going to tackle it
03/01/2024	- Had questions about the gears which we wanted to ask in the tutorials - Gathered a list of questions for both the TA and other teams - Did research to find solutions to help with out problems
03/03/2024	- Began working on the embodiment design report and presentation - Split the work between each group member - Joseph: 1.0, 2.2, 2.5 - Syed: Video and 2.5 - Justin: 2.1, 2.3, 2.4 - Mian Mahmood: 2.2, 2.5 - Abishan: Video and 2.4
03/08/2024	- Had concerns about how the gearbox is going to work and fit in - Spent ample time designing a solution for it
03/09/2024	- Started modelling of the definitive design - Contemplated changes to the frame and the structure of the kart - Decided to make the kart longer due to being able to disassemble and be put into 20x20x40cm box

03/11/2024	- Finished our calculations and 3D CAD models of our design - Began the predicted performance and finished it later in the day - Started to create an outline for the Embodiment Design Presentation
03/12/2024	- Added finishing touches to the Embodiment Design Report - Edited each group member's presentation video section together - Completed the Embodiment Design Presentation