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Abstract

Every design process involves the use of engineering knowledge, the creation of prototypes, and the involvement of multiple perspectives. In the case of a vehicle powered by elastic bands, knowledge of energy and gears was necessary, and the ability to visualize and embody a design was imperative. Communication, engineering discipline, and attention all aid along the path to creating a successful design. Structure, movement, power, and connectivity are all integral to the success of the vehicle. Embodiments of the different systems were combined to create multiple concepts, and these concepts were compared to each other. Through the creation of early prototypes, adjustments were made to each concept - all improving on the previous design to create a better iteration each time. All aspects of the final design, including mass and component properties, allowed for engineering calculations to be done and used as a reference for analysis. The combination of knowledge, iterations, and communication allow for the design of a vehicle to take place.

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Introduction

The concept of this project was to understand the use of primary engineering design skills and traits by making a fully functional prototype from a virtual design with the support of a team of students. The team successfully attempted to design a fast pace four-wheel vehicle that was powered by elastic potential energy that would be converted to kinetic energy. Each member of the team expected to learn principle engineering skills such as CAD designing, the energy conversion principle(i.e. elastic potential energy to kinetic energy) and the functionality of a gear system. As the project demanded a strong team effort, this project developed soft core skills amongst each team member such as interpersonal skills, responsibility, time management, multitasking and working under stress.

As the concept of such a project is relatively new to team members, there is bound to be errors in design and lapse of judgment by the team members. Possible error in design could include

1. Inaccurate measurement of parts thus causing failure in the final product.
2. The cut-out pieces do not comply with each other due to inconsistency in the embodiments.

Lapse of judgement could include

1. The gear system could be incorrectly designed due to lack of conceptual understanding by the designer.
2. A couple of minors parts(i.e. Fasteners) would have omitted by the designer accidentally during the designing process thus ending with an incomplete project.
3. Failure in communication between the member resulting in a product that is not approved by all members.

Throughout this project, the team would undergo a process of constant brainstorming to finalize on a specific concept sketch. The decided sketch would then be virtually made on a CAD software (SolidWorks) by members of the team which would then sent out for printing. The cut-out pieces will be then assembled by the team over the course of a week and will be ready for the competition.

Discussion of the Design

When designing a car, many components need to be thought about and researched to make the car perform with efficiency and ease. The major aspects that need to be looked at in depth are the structural system used, movement system, user interface, power system, medium of connecting all the parts together, axle system and the launch system. These aspects of the design of the car will define whether it will work efficiently or if it will fail.

When thinking about the structural system of the car, one thinks about how the car's body will look and how it is shaped. The structural system of the car is vital since this will determine what the operator can do with the car [1]. For example, if the car is too big or tall, it will be restricted to where it can go. The structural system needs to be reliable, aerodynamic and have good distribution of weight so that it does not tip over. The advantages of choosing the best structural system are that the car would operate in a familiar manner since we would choose a reliable or tried and tested structural system, it would move as fast is it could if we choose the most aerodynamic model and it will be stable and sturdy if its weight is distributed nicely. The advantage of having a structural system is that the car would have a sturdy body from which the parts are built off of.

The movement system of the car is the way the car interacts with its surroundings to move a certain distance. The car can interact with the ground that it is moving over. Obviously, the movement system that makes the most sense for a car is wheels since it is the most reliable and most common movement system used. The advantage of having a reliable and good movement system are that the car will move efficiently and smoothly when interacting with its surroundings.

The user interface is the interface that the user interacts with on the car to make it move on its own. The user interface is vital since if it is not easily accessible or easy to use, it will be harder for the user to do what it must to the car. If the user interface is complex and complicated, the user will not know how to make it do its intended function. The advantage of having a good user interface are that the user will operate the car will ease, both in terms of accessibility and usability.

The power system of the car is how the car will be able to run on its own without the use of any external parts. Essentially its its own engine system, the system it has to power itself to move. The power system must be strong and efficient enough to provide enough energy to the car to make it move and keep moving. The advantage of having a good power system is that the car would be able to go faster and farther for longer time than cars with a less powerful power system.

The medium of connecting the parts together is the system that is used to connect the different components of the car to put them together to build the car. The medium of connecting everything is vital since it makes the car sturdy and if the components are not connected properly, the car could fall apart or it could not work as well as it should. The advantages of having a good medium of connection is that the car becomes sturdier and there would be less of a chance for it to fall apart at a given moment. Also if they are connected well, some components of the car could perform better since it they would not be as loose. For example, if the wheels are loose then they would not move as efficiently then wheels that are rigid and they move as one with the axle system of the car.

The axle system of the car is the rod that is connected to the wheels of the car that keeps the wheels a fixed distance apart and makes the wheels spin at the same rate of the rod part of the system system [2]. The advantage of having a good axle system that can securely move with ease is that it will cause the cars wheels the move at a higher, more consistent and predictable rate.

The launch system of the car is the method from which the car will get itself moving and keep itself moving for a certain amount of time. The launch system uses stored potential energy which it can convert to kinetic energy to make the car move. The advantage of choosing the most effective launch system is that the car will be able to efficiently convert its stored potential energy to the kinetic energy needed to make it move and keep it moving.

There are other aspects that need to be taken into consideration when designing a car. One of these aspects is the weight of the car. If it is too heavy, the car will not be as fast as it could be if it was lighter. This is because the heavier car is exerting a greater normal force on the ground which means that the friction will increase as well, thus making the heavier car slower since more friction will be working against it. Another aspect to take into consideration is the location of the center of gravity since this is the balance point of an object. If the center of gravity is in a poor location, the car will not have good balance and would have a greater chance to tip over and fall. In general, its stability will not be very good [3]. Another aspect that needs to be considered is how high the bottom of the body is off the floor. This also ties in with the center of gravity since it is nice to have the center of gravity low to the ground and this is affected by how high it is off the floor. Furthermore, if it is too low, it could get caught on certain objects or obstacles that would hit the bottom of the body and interfere with the cars intended movement.

Materials Body(ies) → Systems↓				
Structural System	V shape Body	Box Shape Body	Line Shape Body	
Movement System	Wheels 3	Wheels 4	Continuous track wheels	
User Interface	Hooks	Wooden Stick		
Power System	Elastic Energy (Elastic band)			
Connecting System	Epoxy Glue	String	Nuts and bolts	
Axle System	Wooden Dowel Stick			

Table 1.0: Morphological Chart

Morphological Chart
1. V shaped Body
The shape of the vehicle body is inspired by the letter V. THe idea behind this design is to provide a better aerodynamic structure for the vehicle with minimal undesired weight being carried by it.

2. Box Shaped Body
The shape of the vehicle body is rectangle with a slot in the middle. The box shaped body a provides a more uniform and larger surface area for the axle connected to wheel to hold on to. The slot in middle allows the use of the elastic band that is connected by a hook inside the slot.

3. Line Shaped Body
The shape of the vehicle body is streamlined making it a narrow in width and longer in the length. This body proves to be aerodynamically strong due to its streamlined structure. The body would have a “through hole” on the rear end to allow the axle connected to back-tyres to fit in. The base in the front would be curved inwards to allow a front tyre to fit in.

4. Three Wheel System
The vehicle could consist of 3 wheels to travel/rest on - 1 at the front-end and 2 at the backend of the body. The chief advantage of a 3 wheel is better aerodynamic structure.

5. Four Wheel System
The vehicle could consist of 4 wheels to travel/rest on- 2 at the front-end and 2 at the backend of the body. The chief advantage of a 4 wheel is the stability of the vehicle avoiding unnecessary rolls or tumbles a 3 wheeler car is more likely cause.

6. Continuous Track Wheel
The continuous track wheel are is a system where the vehicle propelled by a continuous band/string that is powered by 2 or more wheels. The key advantage of the caterpillar tracks is it’s stability. As there is a larger surface of the movement system of the car in contact with the ground, the vehicle would be firmly positioned on the ground while in motion [4].

7. Hooks
The sole purpose of the hooks is to act as a medium connecting the uncoiling elastic band and the gear system. The user interacts with the hook by rotating it, thus coiling the elastic band attached to it. This creates an elastic potential energy. Once the user is satisfied with amount the elastic band is recoiled, the user places the vehicle on the floor and sets the hook free to move.

8. Wooden Stick
In vehicle with a single gear, an elastic band is attached to the gear. The gear is placed on the wooden axle of the rear-end tyres. The elastic band is held in the front of the vehicle and is stretched to backend of the car, to be recoiled. The wooden stick is the backend would be rotated clockwise to recoil the elastic band by the user. Once the user is satisfied with amount the elastic band is recoiled, the user places the vehicle on the floor and sets the wooden stick free to uncoil itself.

9. Elastic Band
The elastic band is one method to provide the propulsion to the vehicle. As explained in the previous embodiments, the elastic is stretched thus increasing the elastic potential energy. This potential is converted to kinetic energy which thus powers the vehicle to move.

10. Epoxy Glue
The role of the Epoxy is to join parts together using its adhesive properties. Eg. The body and the tube through which the axle can rotate freely in.

11. String
For the purpose of this project, the string is used to loosely tie the hook and a shaft to allow the free horizontal rotation of the hook considering minor displacement of its axis of rotation.
12. Nut and Bolt
For the purpose of this project the nut is used as a fastener to keep the gear system steady and in contact with each other. The bolt is used to add weight at the front end of the body to keep the centre of gravity in the middle. An uneven centre of gravity can cause tipping over, toppling and turbulence of the vehicle.

13. Wooden Dowel Stick
The wooden dowel stick is used as an axle for the frontend and the backend wheels. There would also be a gear system placed on the backend wooden dowel to rotate the wheel. This pushes the car forward.

Concept sketches

Concept 1

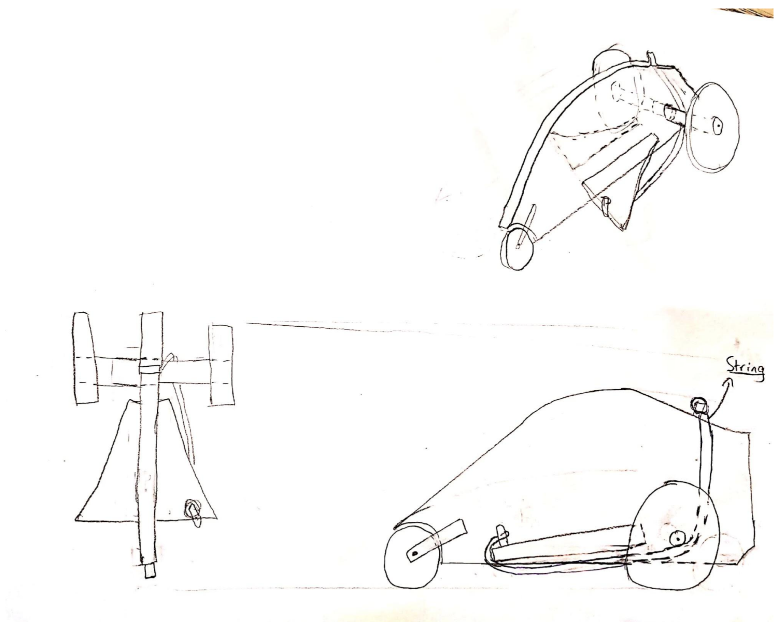

Figure 1.1: concept 1

Structures used:

1. Line Shape Body
2. 3 Wheels
3. Hooks
4. Strings
5. Screw/Bolt
6. Wooden Dowel Stick

This body is a line shaped structure. The string is connected to one end of the body which is knotted around the axle of the cart. The other end of the string is wrapped around to the hook on the top of the cart. The user coils the string around the hooks creating elastic potential energy which thus propels the car forward.

Concept 2

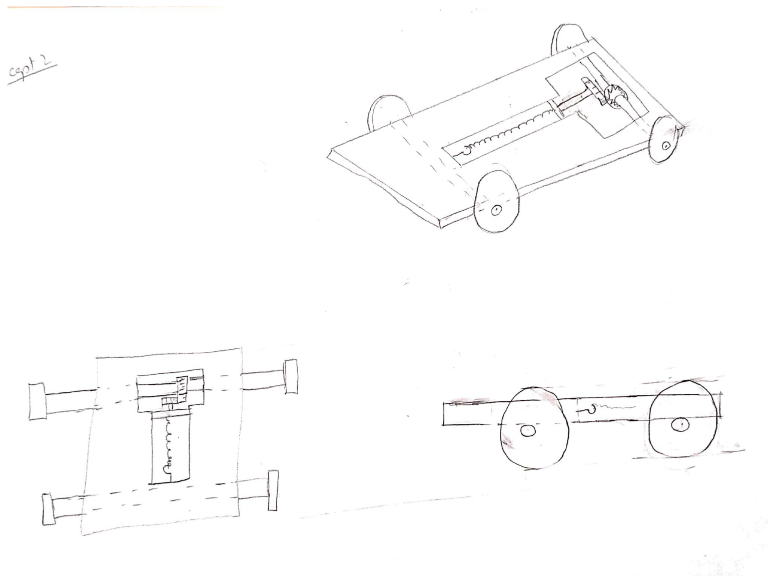

Figure 1.2: Concept 2

Structures used:

1. Box Shape Body
2. 4 Wheels
3. Hook
4. Elastic Band
5. Gear System
6. Wooden Dowel Stick

The user coils the elastic band which produces the potential elastic energy thus propelling the car forwards. While simplistic, this is a good balance lightweight and weight balance.

Concept 3

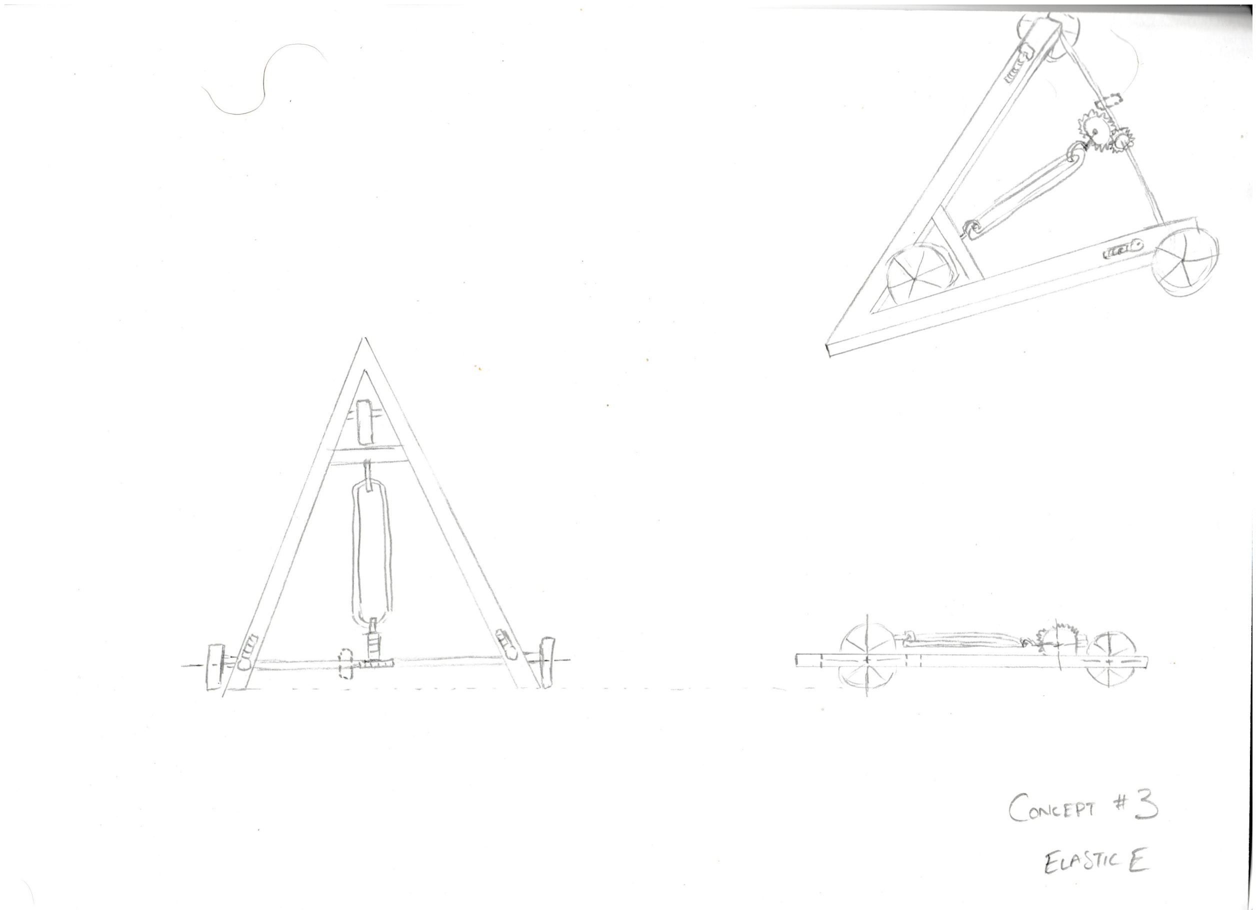

Figure 1.3: concept 3

Structures used:

1. V shape
2. 3 Wheels
3. Hooks
4. Elastic E
5. Epoxy Glue
6. Wooden Dowel Stick

In concept 3, the rear axle is spun clockwise to twist the elastic band, until it is let go, converting elastic potential energy to rotational energy throughout the gearing mechanism, and linear kinetic energy through the wheels. The triangular shape allows for 3 wheels to be used without compromising on balance or stability.

Concept 4

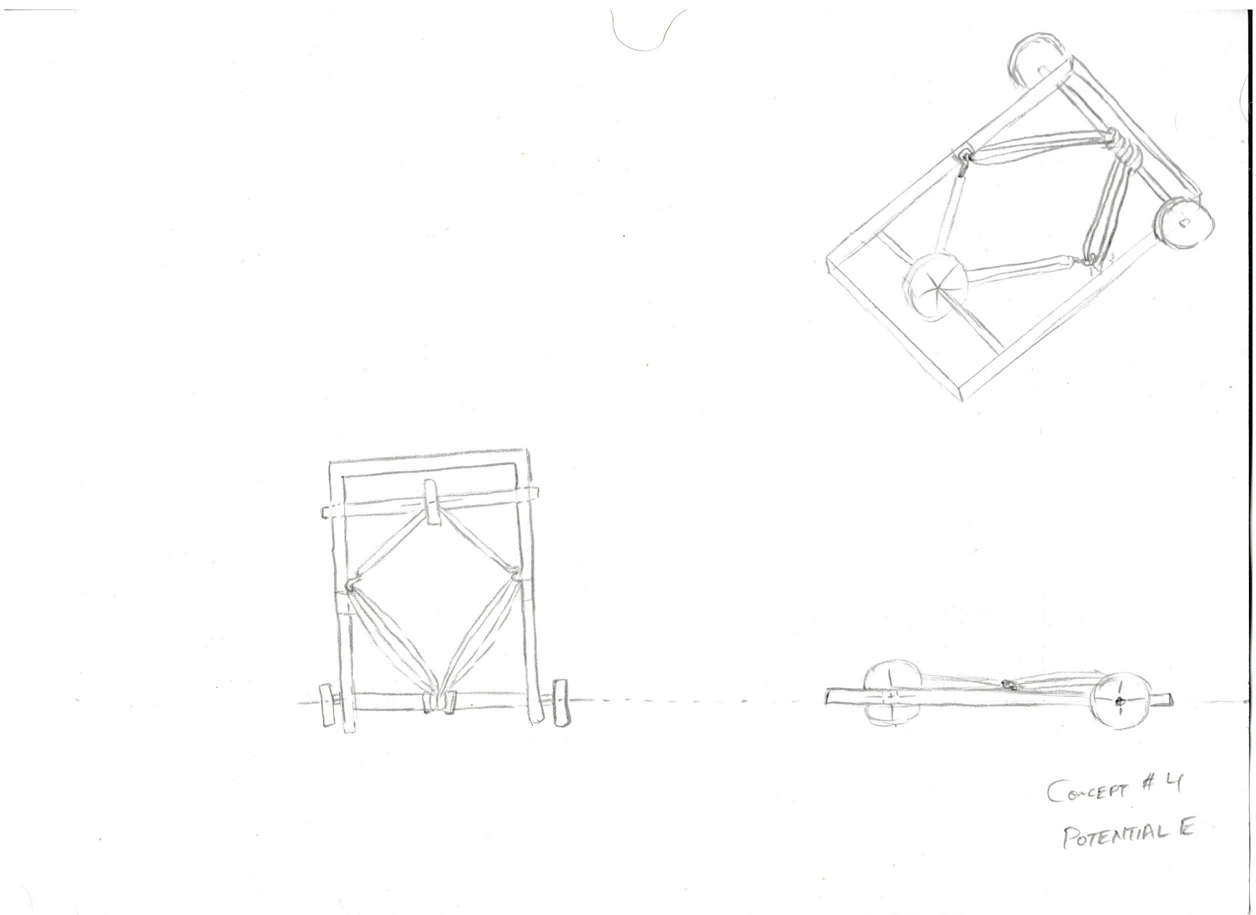

Figure 1.4: concept 4

Structures used:

1. Box Shape
2. 3 Wheels
3. Hooks
4. Elastic Energy (Elastic Band)
5. Epoxy Glue
6. Wooden Dowel Stick

In concept 4, the car is propelled by a falling mass tied to a string that rotates the rear axle, converting potential energy to rotational and linear kinetic. While the box shape hollowed out body is good for a lightweight chassis, it does compromise aerodynamics

Concept 5:

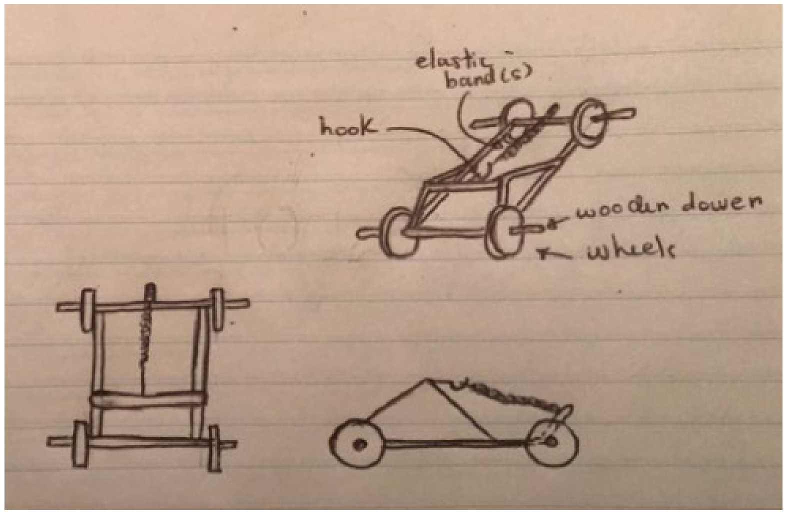

Figure 1.5: concept 5

Structures used:

1. Box shape
2. 4 Wheels
3. Hooks
4. Elastic Energy (Elastic Band)
5. Epoxy glue
6. Wooden dowel stick

In concept 5, to make the car move, the car must be pulled backwards (pulled towards side without the hook) so that the elastic band twist around which creates elastic potential energy. When the car is let go, the band unwinds which propels the car forwards causing it to move.

Concept 6:

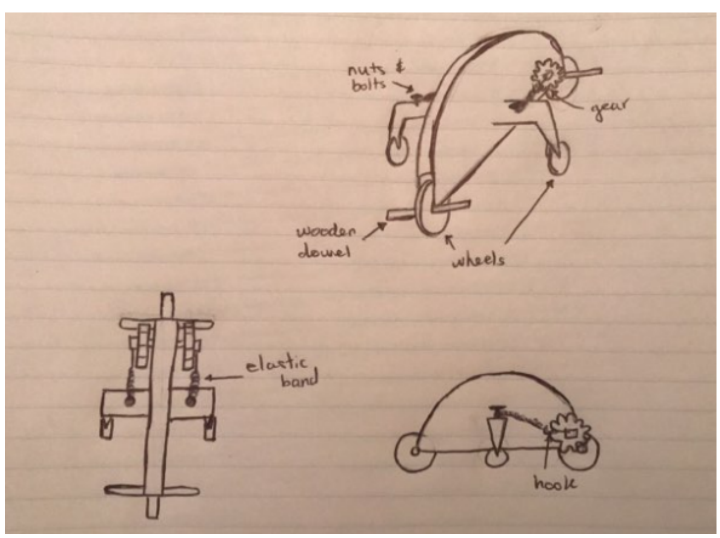

Figure 1.6: concept 6

Structures used:

1. Line shape
2. 4 Wheels
3. Hooks
4. Elastic Energy (Elastic band)
5. Nuts and bolts
6. Wooden dowel stick

In concept 6, the car relies on a gear system and elastic bands to make it move. To make the car move on its own, the car must be pulled backwards (towards side with gears) which causes the elastic band to wind up. This elastic band is attached to the gears which is contact with the wooden dowel. When the car is let go, the elastic band unwinds which causes the gears to spin which causes the axle to spin and then the wheels to spin. This makes the car move.

Concept 7:

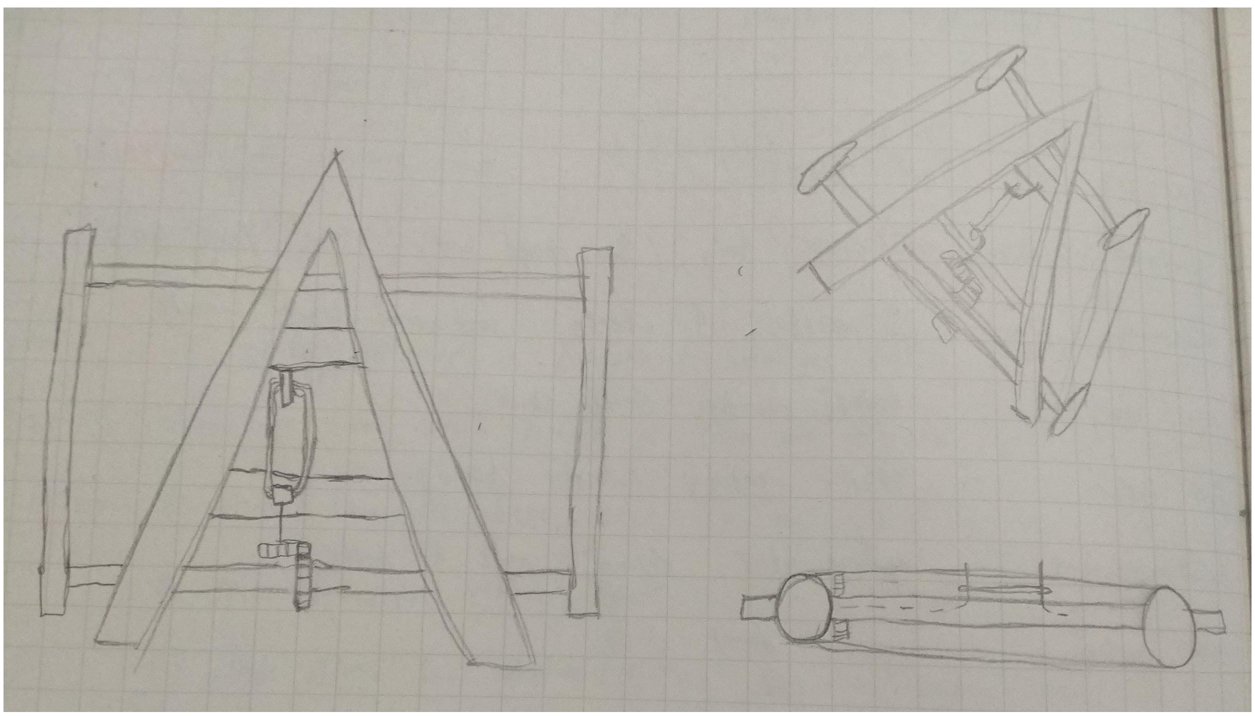

Figure 1.7: Concept 7

Structures used:

1. V shape body
2. Continuous track wheels
3. Hooks
4. Elastic energy (elastic band)
5. Epoxy glue
6. Wooden dowel stick

In concept 7, the body has the shape of a V. The continuous track wheels allow for all points of contact to help propel the vehicle forward. One hook attached to the V-frame has one end of the rubber band fixed to it; the other end is attached to another hook which is free to rotate and power a gear to turn the rear axle.

Concept 8:

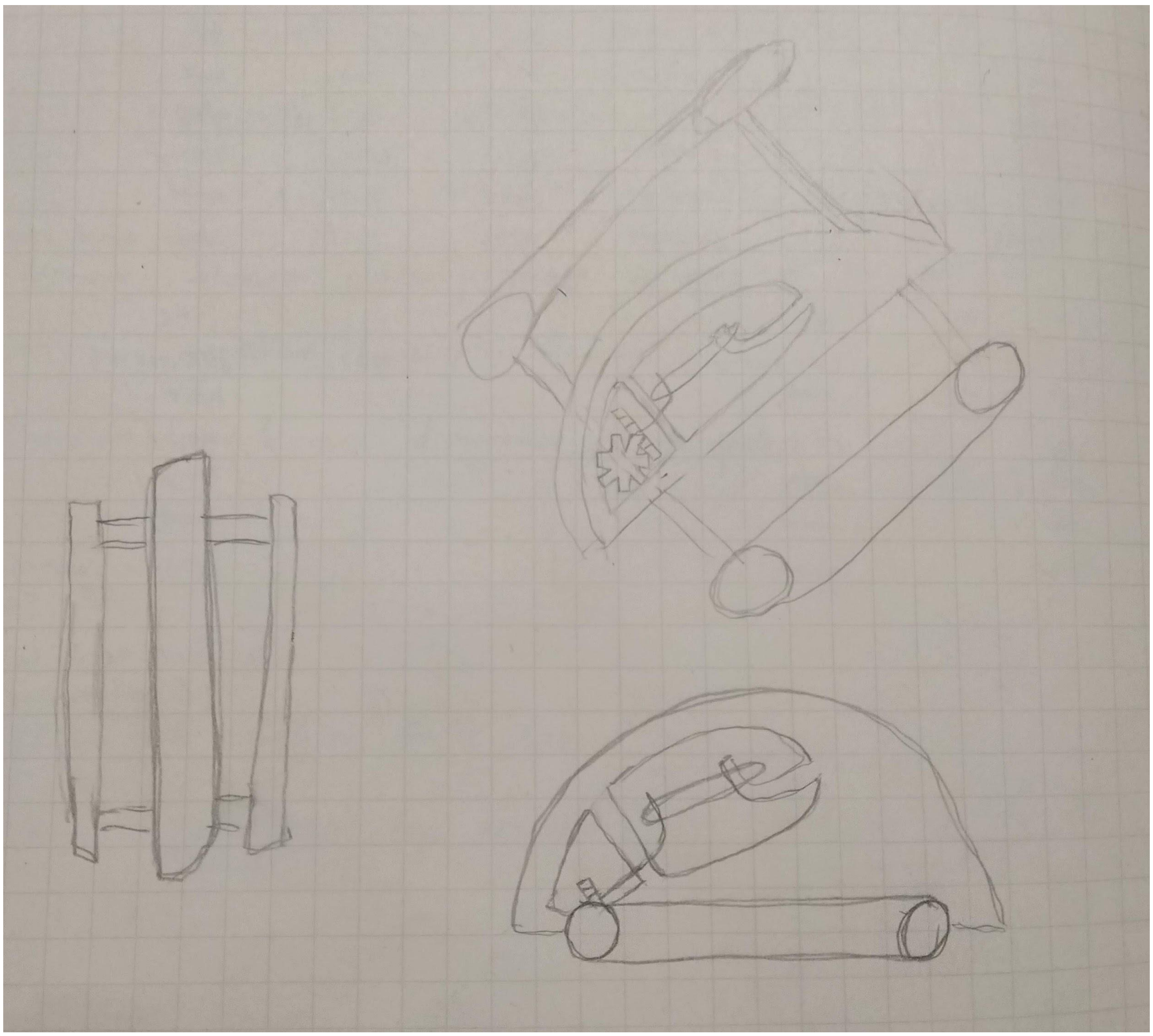

Figure 1.8: Concept 8

Structures used:

1. Line shape body
2. Continuous track wheels
3. Hooks
4. Elastic energy (elastic band)
5. Epoxy glue
6. Wooden dowel stick

In concept 8, the body takes the shape of a straight line when looking from above. The continuous track wheels are powered by the rotation of gears when a rubber band is unwound between hooks in the frame.

Concept 9

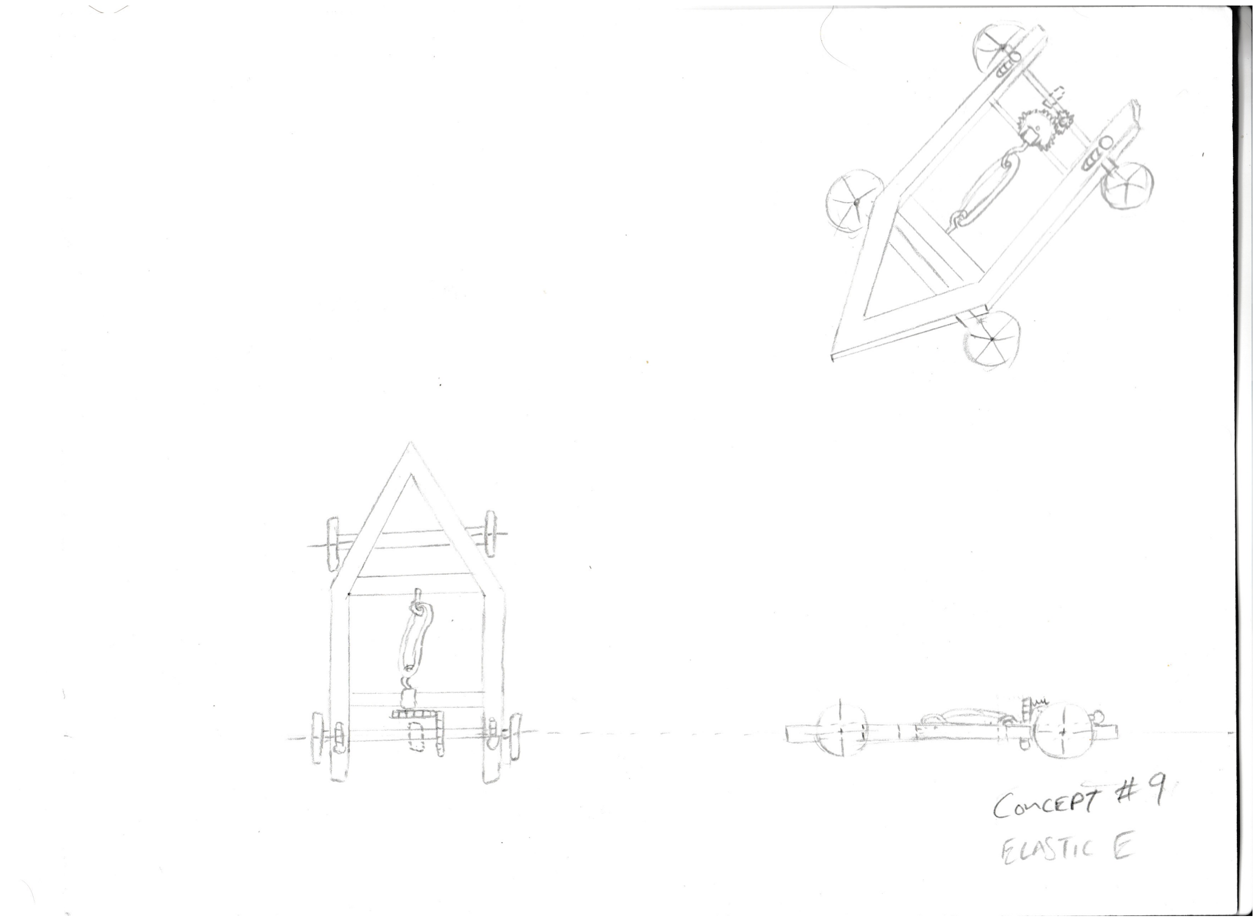

Figure 1.9: Concept 9

Structures used:

1. V + Box shape Body
2. Wheels 4
3. Hooks
4. Elastic Energy (Elastic Band)
5. Epoxy Glue
6. Wooden Dowel Stick

This concept combines the V-shape and Box body to keep a low track width of the wheels in the front, while also allowing a larger wheel span due to the straight portion. This can allow it to be of similar structural rigidity as concept 2, but with less material cut out for the body, making it a lighter weight. It also has a gear system to take advantage of the hollow center fuselage.

Design Evaluation

To evaluate our concepts, we've made a weighted design matrix with the following requirements:

Balance: Weight distribution can easily separate a controllable good car, from a hindered but still good car. Allocating the right amount of weight can create a low center of gravity and increase maneuverability , but hinders vertically oriented structures like that of the box shape design due to the non aerodynamic shape which could cause it to tip.

Amount of time/money required to assemble: Most of this comes down to the number of parts to cut, since that determines the cost of glue/string to assemble, and eventually the time to to make it all work. This can be evident in the physical wheelspan or height dimensions of the car, or the number of parts required to put them together.
Procedure to launch: This is indicative of the “User Interface”, or the steps required to launch the car. Simple design like rotating the elastic band about the rear axle would be our reference, whereas even easier designs such as cars with a gear system that can sustain the torque can

Structural Rigidity: Complex shapes require reinforcement, specifically vertically oriented components. While increasing in things to do to assemble the car, a rigid car can sustain excessive elastic force without deforming the body or dislodging parts.

Portability: Small, simplistic designs are easier to store, and thus, much more simple to repair if dropped by accident. This requirement goes hand in hand with amount of time/money required, but at the cost of structural rigidity and thus, excessive force.

Efficiency of Energy transfer: This comes down to how little transfers of energy type there are from elastic to linear kinetic energy. A gear system, for example, turns elastic energy to rotational kinetic energy through the gears first, then rotational kinetic energy of the wheels, and then linear kinetic energy propelling the car forward.

Concept 2 was chosen as our reference as it handles portability and small parts cut out with its simplistic design, with good energy transfer efficiency by it's directly connected rear axle. It does this by compromising with a torque heavy rear axle, poor structural rigidity due to a single piece fuselage, and additional downforce required by the user to wind it up during launch (due to the weight distribution)

As seen from the matrix below (figure 2.2), we chose directly connected non gear system of Concept #9.

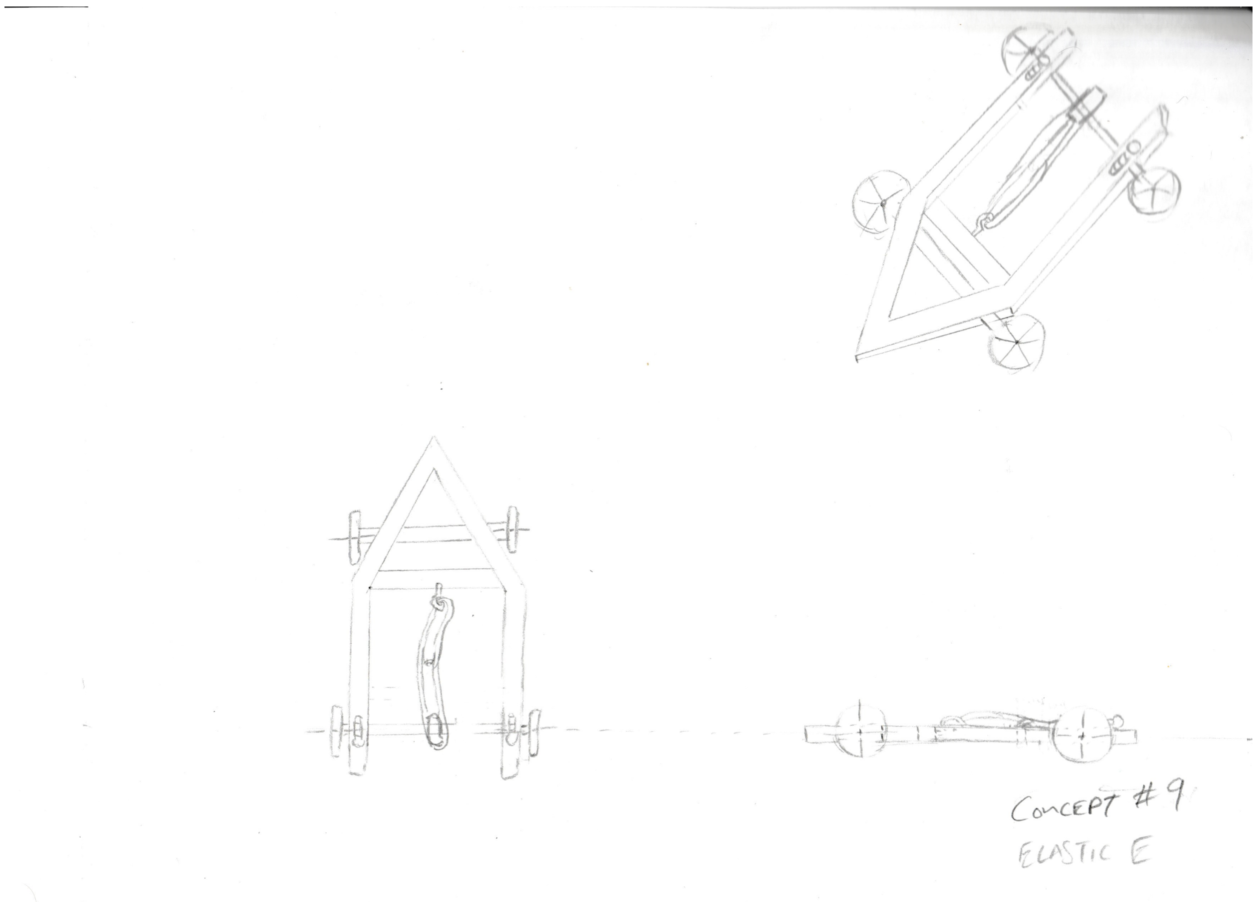

Figure 2.1

ATTRIBUTE	WGT	Concept 2/Reference		Concept 1		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7		Concept 8		Concept 9	
	%	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE
Balance	0.3	0.0	0.0	-1.0	-0.3	-1.0	-0.3	0.0	0.0	1.0	0.3	-1.0	-0.3	2.0	0.5	0.0	0.0	1.0	0.3
Amount for assembly	0.2	0.0	0.0	0.0	0.0	-1.0	-0.2	-2.0	-0.4	0.0	0.0	0.0	0.0	-2.0	-0.4	-1.0	-0.2	0.0	0.0
Procedure for launch	0.1	0.0	0.0	1.0	0.1	2.0	0.1	0.0	0.0	0.0	0.0	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Structural Rigidity	0.2	0.0	0.0	-1.0	-0.2	1.0	0.2	1.0	0.2	1.0	0.2	-1.0	-0.2	1.0	0.2	0.0	0.0	1.0	0.2
Portability	0.1	0.0	0.0	0.0	0.0	-1.0	-0.1	-2.0	-0.2	0.0	0.0	0.0	0.0	-2.0	-0.2	-1.0	-0.1	0.0	0.0
Efficiency for energy transfer	0.2	0.0	0.0	1.0	0.2	-1.0	-0.2	-1.0	-0.2	0.0	0.0	-1.0	-0.2	-1.0	-0.2	-1.0	-0.2	1.0	0.2
			0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0
			0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0
			0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0
			0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0
TOTALS	1.0		0.0		-0.2		-0.5		-0.6		0.5		-0.6		-0.1		-0.5		0.7
RANK			3.0		6.0		7.0		9.0		2.0		9.0		5.0		8.0		1.0

Figure 2.2: Weighted Decision Matrix

First prototype made before receiving cut out parts:

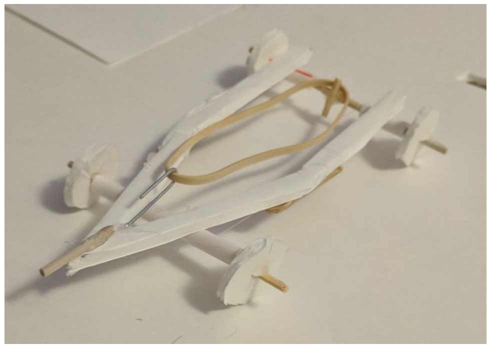

Figure 2.3: Early Prototype

This prototype was made with the same dxf layout cut that was sent to Devin for cutting, albeit with a foam board for the fuselage and wheels, straws for the axle holders, and a smaller diameter dowel than the one provided to us. While only travelling an average of 5cm, it gave us a lot of mistakes to fix early in the development stage. This early prototype didn't have a transmission or a gearing system, it was just to see if the proportions of the car made sense, and to see how viable a directly connected rear axle car would be.

We found the car to initially have a lot of torque about the rear axle if rotated about the axle a minimum of 3 times. While this was partially due to the rear axle rotating within the straw (axle holder), it was mainly due to the directly connected nature of the elastic band rotating the entire car about the rear axle. While the easy fix was to add weight in the back to increase downforce, it would hinder the aerodynamic shape of the fuselage. We concluded it as a last reserve for the uphill test, where initial torque can be beneficiary rough starts.

Lastly, we found that adding a strand of spare elastic band around the wheels can help traction, specifically on polished hardwood or marble floors. We also added a wooden dowel to the rear axle as a failsafe for us if the gear system failed. If the gear system failed, we would simply tie the gear around the wooden dowel that is attached to the rear axle just as seen in our prototype.

Engineering calculations

Mass:

Acrylic sheet volume: 8” * 10” * ⅛” = 8” * 10” * 0.125” = <u>10 in^3</u>
Acrylic sheet mass: <u>174 g</u>
Comparing acrylic mass and volume: 10 in^3 = 174 g ∴ <u>1 in^3 = 17.4 g</u>

Frame mass:
[2 * 9 mm * 100 mm + (72 mm * 101 mm) / 2 - (54 mm * 76 mm) / 2] * 0.125” * (m^2 /1 000 000 mm^2) * (10 000 cm^2 / m^2) * (0.393 701 in / cm $)^2$ * (17.4 g / in^3) = <u>11.408 345 14 g</u>

Mass of wheels:
4 * [π * (31 / 2 mm $)^2$ - π * (3 mm $)^2$] * 0.125” * (m^2 /1 000 000 mm^2) * (10 000 cm^2 / m^2) * (0.393 701 in / cm $)^2$ * (17.4 g / in^3) = <u>9.796 792 339 g</u>

Mass of axle holders:
4 * [π * (6 mm $)^2$ - π * (3 mm $)^2$] * 0.125” * (m^2 /1 000 000 mm^2) * (10 000 cm^2 / m^2) * (0.393 701 in / cm $)^2$ * (17.4 g / in^3) = <u>1.143 841 7 g</u>

Long bar mass:
86 mm * 7 mm * 0.125” * (m^2 /1 000 000 mm^2) * (10 000 cm^2 / m^2) * (0.393 701 in / cm $)^2$ * (17.4 g / in^3) = <u>2.029 498 751 g</u>

Short bar mass:
57 mm * 6 mm * 0.125” * (m^2 /1 000 000 mm^2) * (10 000 cm^2 / m^2) * (0.393 701 in / cm $)^2$ * (17.4 g / in^3) = <u>1.152 971 051 g</u>

Big gear mass:
π * ((23 / 2 mm + 9 mm) / 2 $)^2$ - π * (¼ / 2 in$)^2$ * 0.125” * (m^2 /1 000 000 mm^2) * (10 000 cm^2 / m^2) * (0.393 701 in / cm $)^2$ * (17.4 g / in^3) = <u>1.005 965 202 g</u>

Small gear mass:
π * ((6 mm + 7 / 2 mm) / 2 $)^2$ - π * (1/2 mm$)^2$ * 0.125” * (m^2 /1 000 000 mm^2) * (10 000 cm^2 / m^2) * (0.393 701 in / cm $)^2$ * (17.4 g / in^3) = <u>0.236 314 517 g</u>

Dowel volume = π * (¼ / 2 in$)^2$ * 12” = π * (⅛ in $)^2$ * 12” = π * (0.125 in $)^2$ * 12” = <u>0.589 048 622 in^3</u>
Dowel mass = <u>6 g</u>
Comparing dowel mass and volume: 0.589 048 622 in^3 = 6 g ∴ <u>1 in^3 = 10.185 916 36 g</u>

Long dowel mass:
π * (¼ / 2 in $)^2$ * 105 mm * (m / 1000 mm) * (100 cm / m) * (0.393 701 in / cm) * (10.185 916 36 g / 1 in^3) = <u>2.066 930 25 g</u>

Short dowel mass:

π * (¼ / 2 in $)^2$ * 71 mm * (m / 1000 mm) * (100 cm / m) * (0.393 701 in / cm) * (10.185 916 36 g / 1 in^3) = 1.397 638 55 g

Total mass: **30.238 297 5 g**
Total mass in lb: 30.238 297 5 g * (0.002 204 62 lb / g) = **0.066 663 955 434 45 lb**

Energy Transfer:

Spring constant of elastic band - 0.8 N/cm
No of rubber of used = 2

Maximum stretch of rubber band - 8 in
Rest position- 2.5in

$$\frac{1}{2}k(x - x_0)^2 = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{k*(x-x_0)^2}{m}}$$

$$K = \frac{0.8N}{cm} * \frac{1cm}{0.3937in} * \frac{0.22481\ lbf}{1\ N} = 0.456lbf/in$$

$$v = \sqrt{\frac{0.456*(8-2.5)^2}{m}}$$

Therefore theoretical velocity achieved by the car is 14.384 659 017 790 34 in/s.

$$gravity = 32.2\frac{ft}{s^2}$$

$$\frac{1}{2}k(x - x_0)^2 = mgh$$

$$h = \frac{k(x-x_0)^2}{mg}$$

$$h = \frac{0.456*(8-2.5)^2}{m*32.2}$$

h = 6.426 037 734 726 506

Gear Ratio

$$\frac{r_b}{r_A} = \frac{N_b}{N_A} = \frac{V_b}{V_A}$$ [5]

$$\frac{6}{14} = \frac{N_b}{N_A}$$

$$\frac{0.125}{0.33} = \frac{r_b}{r_A}$$

Gear ratio(Small gear : Big Gear) = 1 : 2.64

Aerodynamics
- The V shaped front of the car enables a better posture as it cut through the wind and reduce drag coefficient.
- The axle in the front is smaller to the axle in the rear. This model works well to keep the vehicle in a straight line. The larger rear-end axle reduces the horizontal displacement(turbulence) of the car thus enabling the vehicle to move in a straight line [8].

Conclusions

The main goal of this project was to get the students to apply the knowledge they have acquired over the years from engineering and applying it to make a rubber band powered car. This project has also taught us many things. We learned how the elastic potential energy of an elastic band be can converted to kinetic energy which makes it move forward. We knew this concept from our many physics related courses, but now we learned how to apply these concepts to a working model and observing the results. One part of the car that worked well was it's overall lightweight, requiring minimal rotation of the elastic band for translational movement. Another thing we learned is that the inclusion of a gear system greatly improves the performance of the car itself [6]. With our previous knowledge, we thought that the best idea was to simply attach a rubber band to the rear axle and wind it up as seen in our prototype model. Upon investigation of other designs and ideas, we learned that if gears were incorporated in the design of our car, the performance of the car would greatly improve as compared to out prototype model, while also reducing the downforce required to launch it each time as the gears could handle the torque build up given the correct gear ratio [6]. Another thing that we learned is that wheel traction is an important part of the design. We learned through experiments with our car that when the wheels have more traction (by wrapping rubber bands around them), the car grips the floor better and makes the car move more efficiently. When we had less traction on the wheels, the wheels tended to slip a lot which caused the car not to move so efficiently since it could not get a firm hold on the ground.

In our design of the car, some components worked well. One of these components include the addition of the elastic bands around the rear tires of the car. Elastic bands were cut and glued around the surface of the wheel that it is in contact with the ground. The traction between the elastic bands and the ground are much higher than the the traction between the acrylic and the ground which was observed by own experimentation. This component worked well since the elastic band wheels now hold onto the ground better which makes it easier to propel itself forward while also reducing the risk of the wheels spinning around really fast while the car does not move since it cannot hold onto the ground. Another component that worked well is the body shape of the car. The body of the car proved to be a stable and reliable body. It managed to maintain its shape and stability throughout our process of testing and assembling of the car. From all our components, these parts of the design worked well.

On the other hand, there are multiple parts in the design that could be changed. One thing that could have been changed was how big the gears were and their overall design. They were too brittle and small which made it extremely difficult to work with since we always had to be extra cautious to not damage it. The overall design of both gears have to be changed as well since the teeth do not even line up with each other which means that when one spins, the other will not since it would get stuck on the other gear or it would simply slip out of its slot. If the gears were bigger and they fit together properly, the car's gear system would have worked, but instead they do not fit and the gear system of the car fails. Another part that could be changed is method by which all the parts of the car were connected. We were using a strong glue (Krazy Glue [7]) to bind the parts together, but what ended up happening many times was that the pieces would fall or break off since they would not hold was not strong enough. If this was changed and the parts were secured in a stronger way, we would not have run into these problems. The distance between the body and the ground is another part of the design that could have been changed. Since we made our body to be relatively low to the ground so that it would be more stable since its center of gravity would be low, this created many problems in the assembling of the car. This is because multiple parts had to be cut so that it did not interact with the floor. The positioning of the parts could have also been different so that there is no part that is faulty or bad. For example, one of the front wheels is not lined up perfectly straight which causes it to wobble every time it spins around. This in turn, causes the car's direction to start to turn slightly and the front axle would start to wobble as well. Many parts could have been changed which would have determined if our car would move or not.

When making the design, there were also a couple of sources of error that could have affected the outcome of our car. One of the main sources of error that is the blame for the failure of our car to have a working gear system is human error. We did not dimension the gears properly so that they would fit together perfectly, instead they do not fit which means that the gear system fails completely. Another possible source of error is in the laser cutter machine that was used to cut out all of our parts before assembly could have some faulty equipment in it. This would cause the laser cutter to make inaccurate dimensions and cuts which would have affected our car.

In conclusion, this project taught the members of this group many things about the process of designing cars. It taught us how cars are designed and the things to consider when designing these cars. We learned about how we can apply how theoretical engineering knowledge to experimental practice by making our own car. After making the design, we discovered which parts worked best for the car and which parts can be changed to further improve the car design. We wish our design of the car would have worked with the fear system, but unfortunately we made too many mistakes and errors in the designing process.

Recommendations

Given the opportunity to do this project again:

More comprehensive prototypes could be built. This could help eliminate more early mistakes, such as failing to check for ground clearance during different tests.

A different approach to the gear system could be taken. The addition of a smaller rear stabilizer to the first could allow for a row of sequential gear ratios to choose from. This choice of gear ratios could help for different tests, such as the use of smaller gear ratios to help in the climbing test.

There would be an adjustment to the wheels and axles. To remove axial movement due to turbulence, the front axle could be glued onto the axle holder; this would allow the wheels to rotate independently. A location fixation by a nut could help them to not rotate out of the axle, and this could minimize the turbulence by only allowing the wheels to move independently of each other. In addition, the fixation of the front axle location would be acceptable as it does not contribute to the storing of potential energy, unlike the rear axle which must remain free for the gear to spin. So long as the front wheels are able to rotate, this adjusted design could prove to provide added stability for the final result.

The final result would have multiple parts, increased strength, and be more efficient overall. Spare parts for small items such as gears and wheels would help during construction, and could also be used to make parts thicker. This allows for stronger forces to act on the parts, compared to the single-layered, 0.125” acrylic part depths which could easily snap and break. For example, a reinforcement of the back wheels or thicker small gears could help with improving traction and rigidity. Finally, a light adhesive could be used primarily and then followed with the stronger adhesive, as to adjust parts in the case of misalignment. A stronger, more rigid, and properly aligned final design with traction could provide much success.

On the note of group work, responsibilities for members should be assigned early in the term. This would assist greatly with time management, and it would also reduce the amount of stress and cramming brought on through short-term work.

Appendix

CAD Drawing

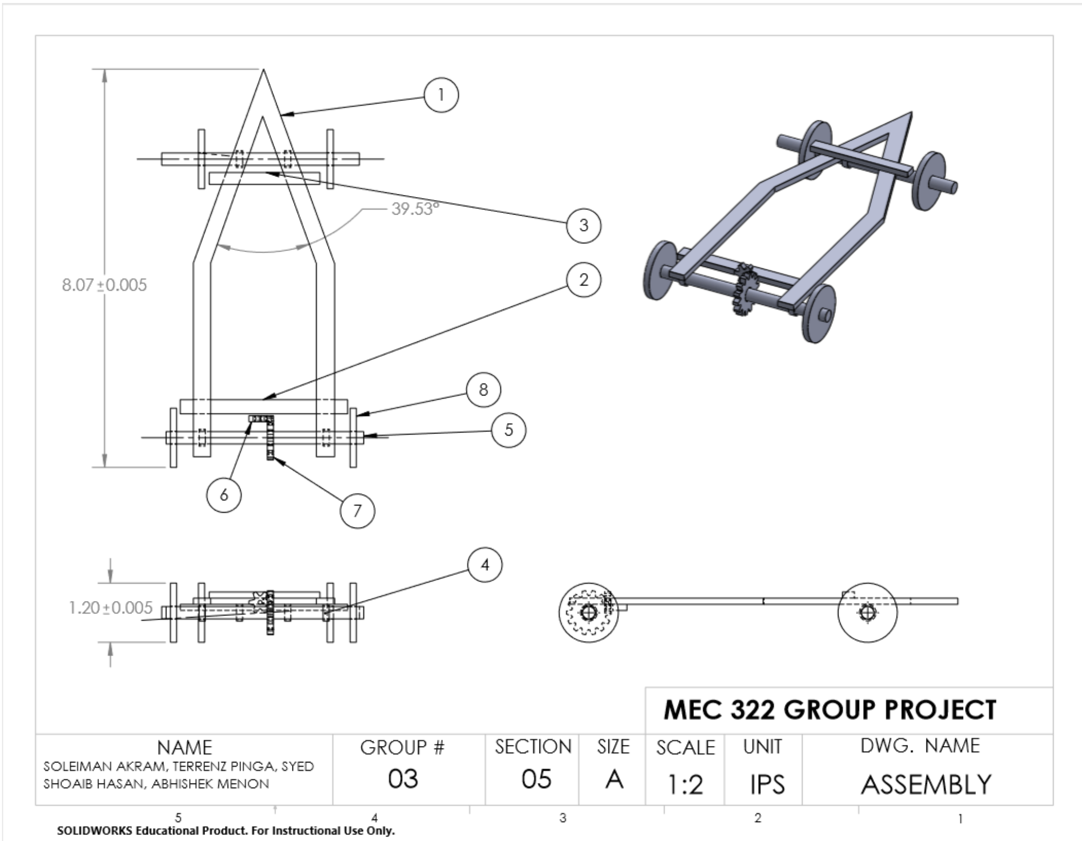

Figure 3.1: Assembly drawing

ITEM NO.	PART NUMBER	QTY.
1	CAR BODY	1
2	BIG BAR	1
3	SMALL BAR	1
4	AXLE HOLDER	4
5	SHAFT (WOODEN DOWEL)	2
6	SMALL GEAR	1
7	BIG GEAR	1
8	WHEEL	4

MEC 322 GROUP PROJECT

NAME	GROUP #	SECTION	SIZE	SCALE	UNIT	DWG. NAME
SOLEIMAN AKRAM, TERRENZ PINGA, SYED SHOAIB HASAN, ABHISHEK MENON	03	05	A			BILL OF MATERIALS

SOLIDWORKS Educational Product. For Instructional Use Only.

Figure 3.2: Bill of Materials Chart

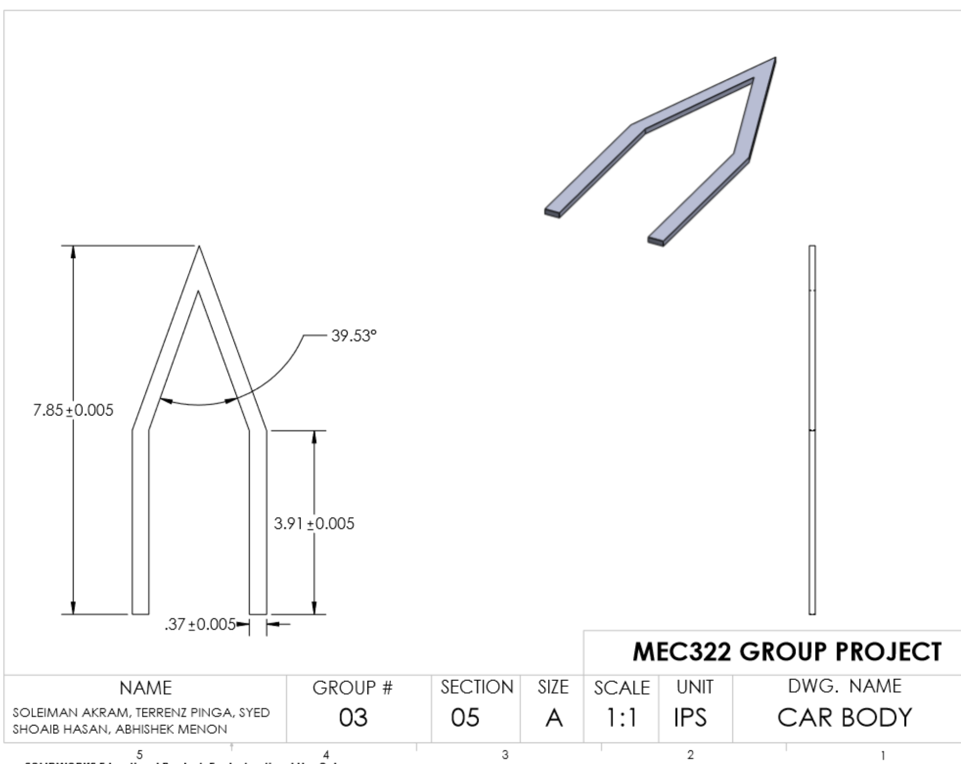

Figure 3.3: Car Body drawing

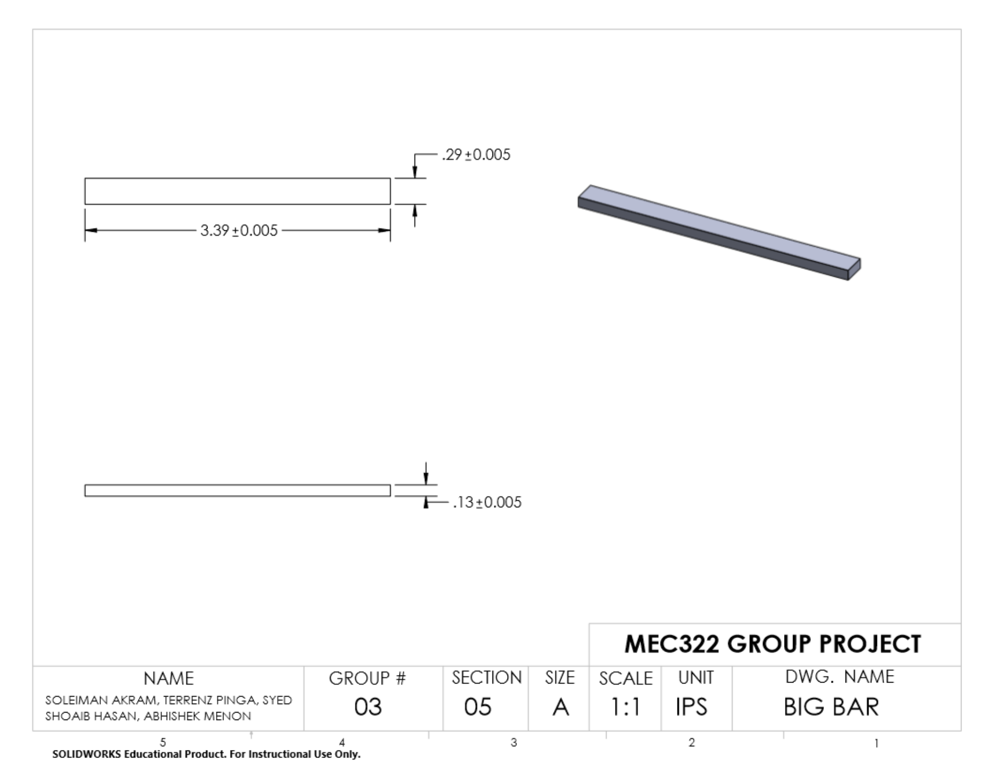

Figure 3.4: Big Bar drawing

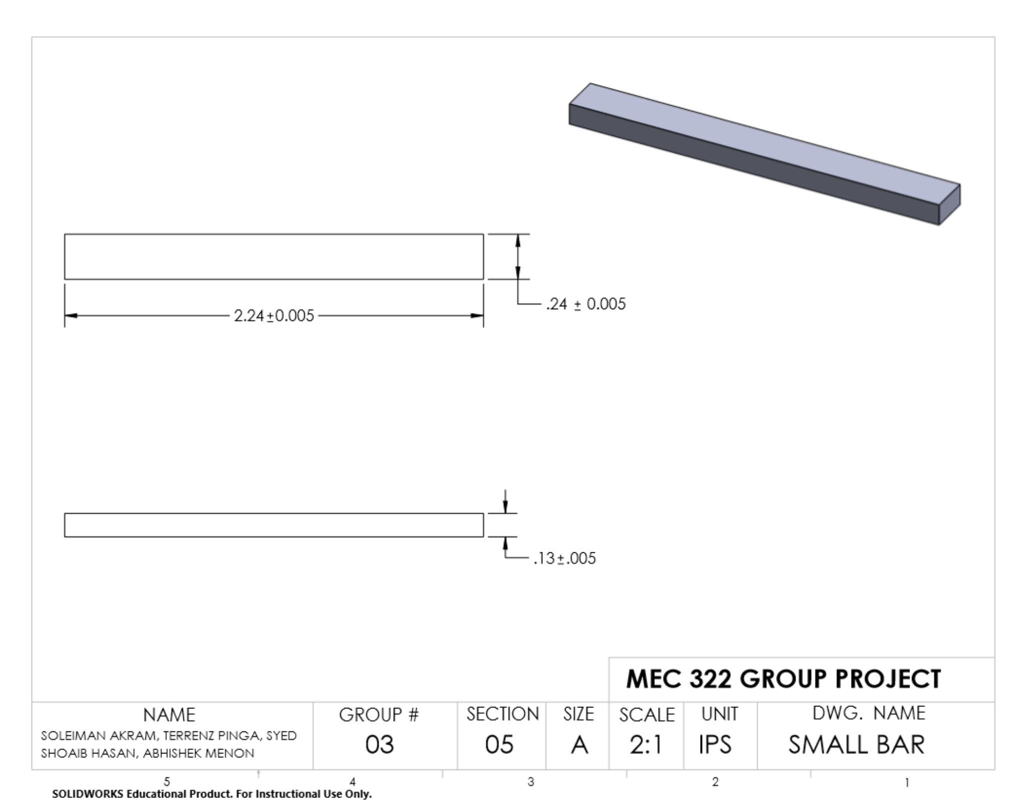

Figure 3.5: Small Bar drawing

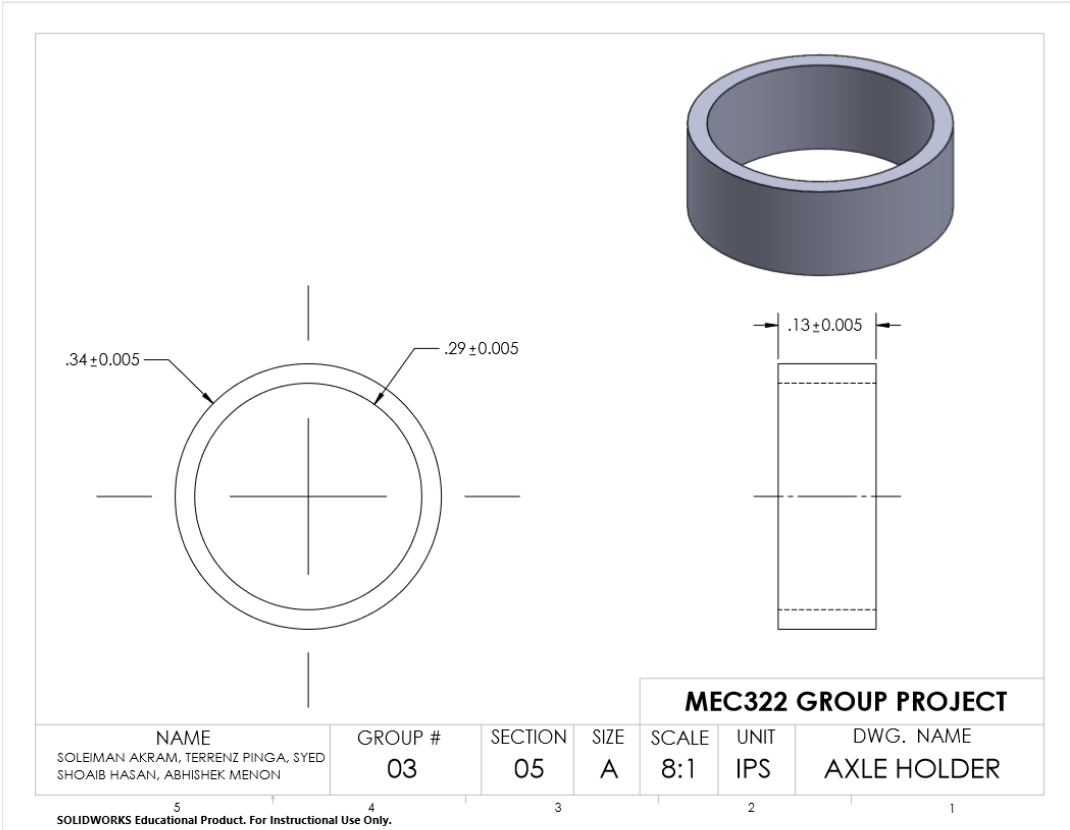

Figure 3.6: Axle Holder drawing

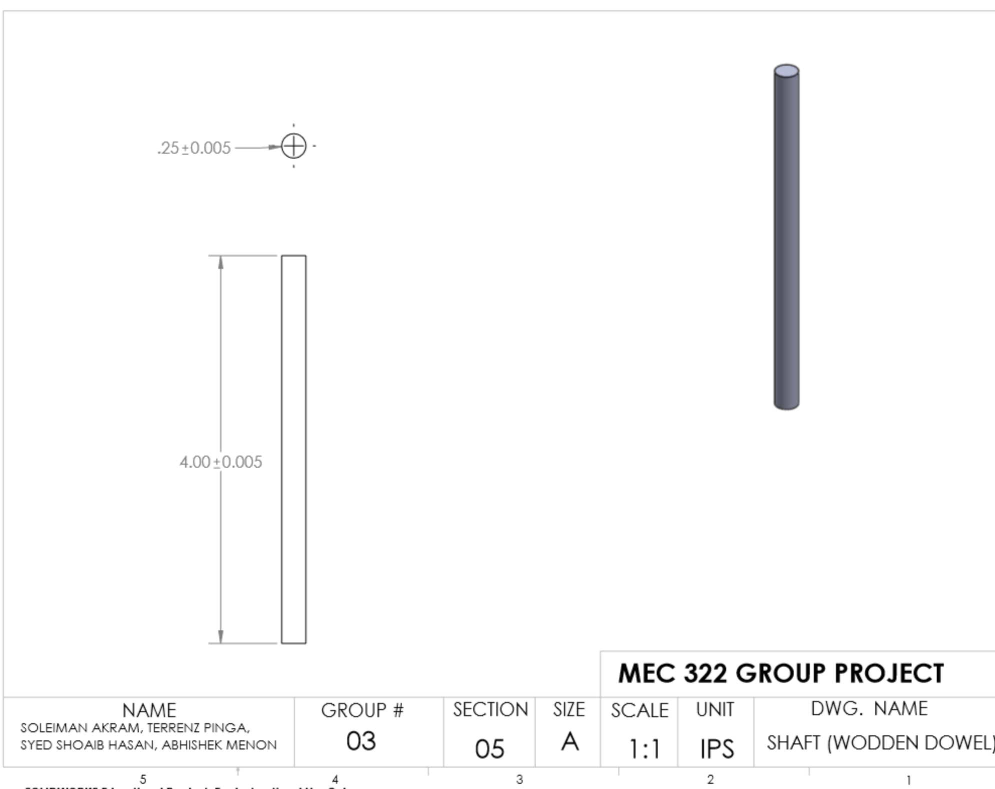

Figure 3.7: Shaft (Wooden Dowel) drawing

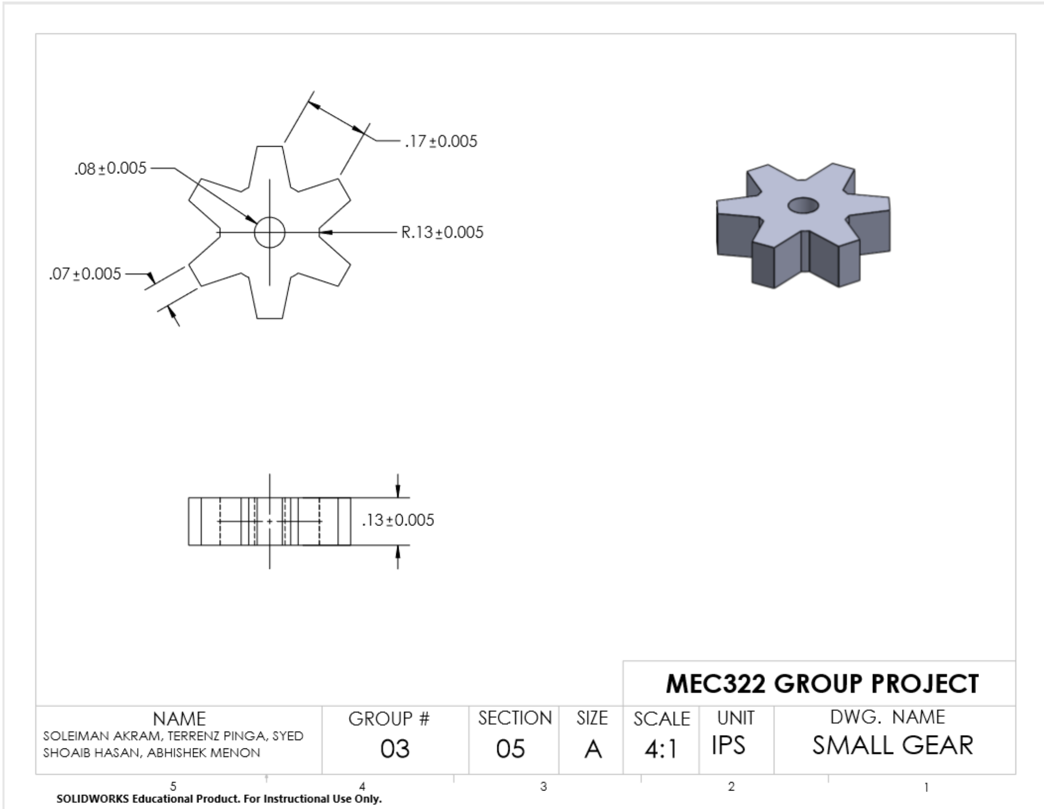

Figure 3.8: Small Gear drawing

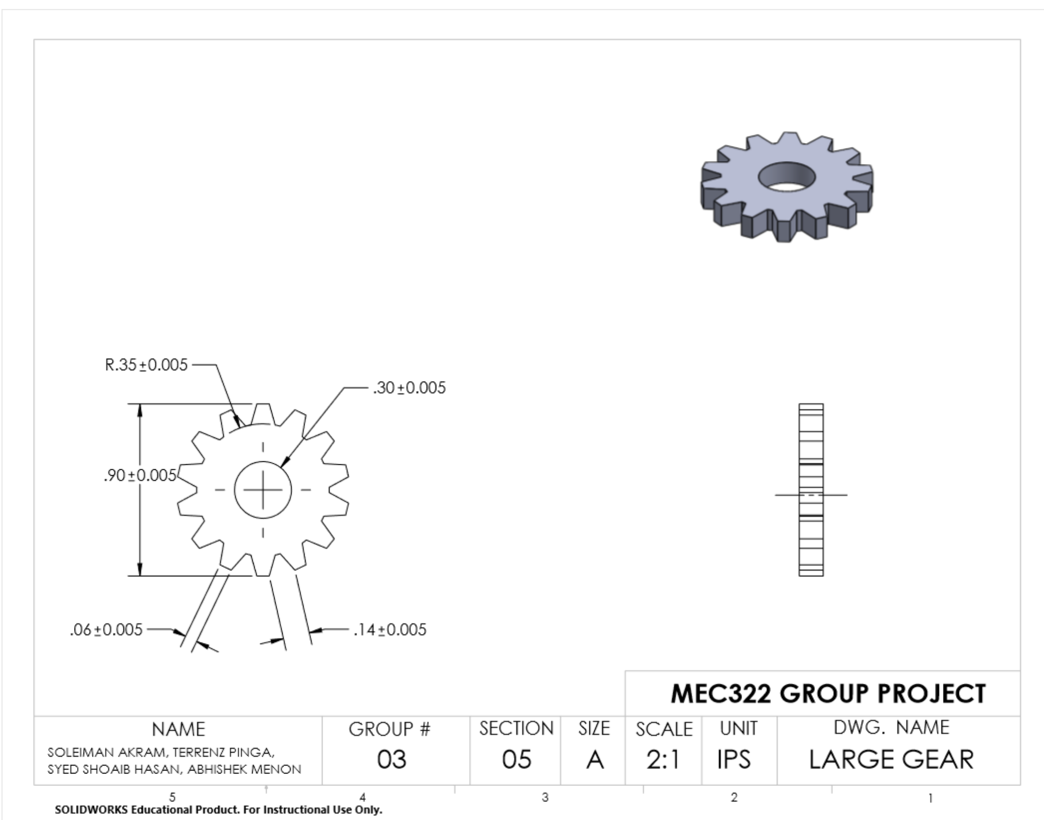

FIgure 3.9: Large Gear drawing

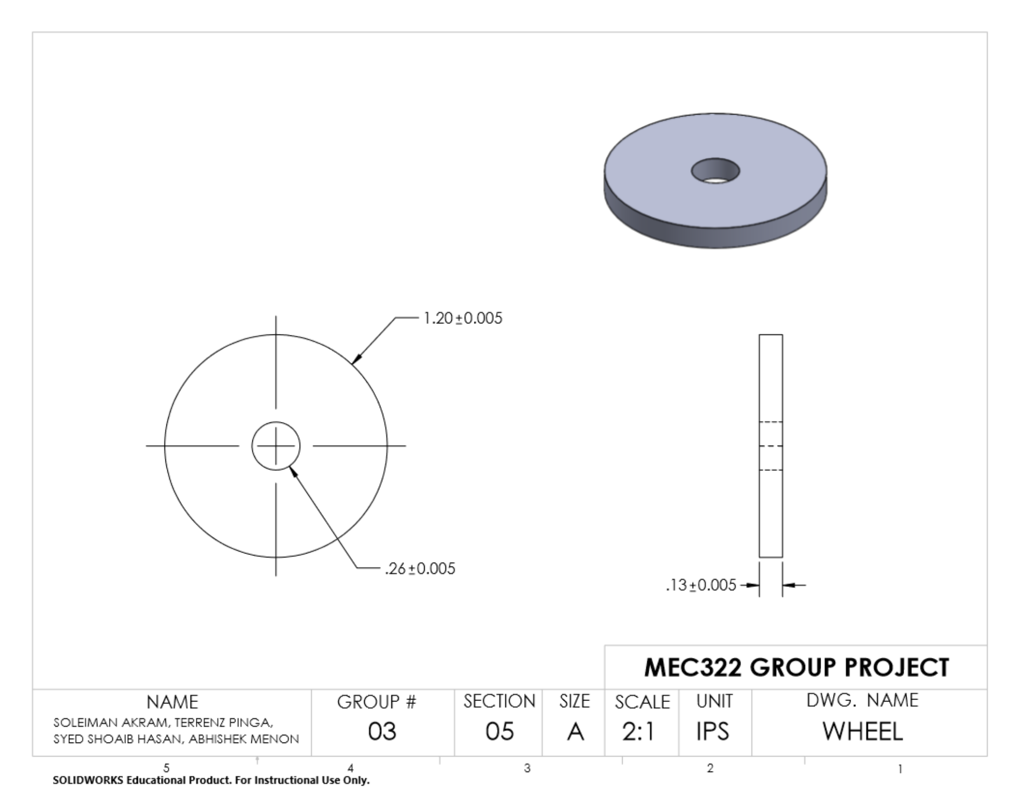

Figure 3.10: Wheel drawing

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