K’nex Car Preliminary Design Review

Client:

Dr. Laura Moody

Project Members:

Ronald Alvarez

Alex Flores

Jerry Tang

Micah Toon

Introduction to Engineering Design

EGR 107

Spring 2018

Abstract

The purpose of the K'nex car project is to introduce students to fundamental engineering design and applications. As students in the Mercer University School of Engineering, we must build a K'nex car solely using K'nex pieces. Our objective is to design a K'nex car with the greatest efficiency for the Hill Climber event. During the rounds of the Hill Climber, vehicles will compete by climbing up hills with specific inclinations during a limited time interval. The inclinations of the hills increases after each round of the competition. We came up with three preliminary design, and we recommended design 2 based on the following merit criteria: weight, velocity, and gear ratio. We will test the speed of our final product on various inclinations; we will also measure the velocity on varying intervals of time and distance; we will test the load that our final product can carry. The tests allow us to get a perspective of our final design's performance in the Hill Climber event, and how to improve our design according to the possible deficiency that could occur during the testing.

Table of Contents

1. Introduction

1.1 Purpose and the Objective of the Project

The K'nex Car design is the final project given in the freshman engineering design class at the Mercer University School of Engineering. For this task, each team is assigned by our instructor. The purpose of the project is to introduce fundamental engineering concepts to the students by giving them the opportunity to work with a client, just as in a professional situation. The objective of the assignment is to build a K'nex car that meets the required project specifications and perform optimally in the Hill Climber competition as assigned by our client–Dr. Laura Moody. In this event, our vehicle must travel in multiple heats across a track at different levels of inclination.

1.2 Real World Applications

This project is relevant to the real world due to the aspect of having to design a product for a client that follows a list of specifications. The K'nex car project is much like a job an engineer would actually have. The project gives students experience with making PDR's and CDR's, and it gives students experience working in groups. By doing this project, students are also gaining experience designing and testing a product. This project gives us an opportunity to make preliminary designs before actually having the materials needed to build the car. This is similar to an actual engineering job in which you have to design your product before being able to build and test it. The K'nex car project has many real world applications, and it gives students experience with skills needed in an actual engineering job.

1.3 Rules for our Competition

Our client, Dr. Laura Moody, assigned us the Hill Climber event. The Hill Climber consists of multiple rounds in which the cars must travel up a hill at a specific inclination. The lane's dimensions are 0.3048 meters wide and 2.4384 meters long. The track's elevation starts at 15.24 cm and increases by 15.24 cm sequentially for six rounds of the competition. Teams have a time limit of 90 seconds to make it to the finish line, and each team's attempt must commence within 60 seconds of being called or they lose that attempt. To win the Hill Climber event, our team's car must be the first to reach the top of the hill in the final round while following all the rules of the event. During the Hill Climber competition, the vehicle must stay in its own lane, and it cannot interfere with other vehicles.

1.4 Vehicle Specifications

The project specifications were also assigned by our client, Dr. Laura Moody. The final product must be constructed only from the components in our parts kit. The teams cannot use glue for construction. Teams may not disassemble or modify the mousetrap, DC motor, and the spring motor in our parts kit. Each attempt must commence within 60 seconds being called. All parts of the K'nex car must travel with the vehicle when climbing. All K'nex cars must start themselves; no other aids are allowed.

1.5 Timeline and Due Dates

Table 1: Timeline and Due Dates

Date	*What's due?*
March 21	K'nex Proposal
March 28	K'nex Car PDR and Presentation
April 4	K'nex written Test Plan
April 6	Competition Day - Engineering Expo
April 18	K'nex Car CDR and Presentation

2. Feasibility Criteria

The feasibility criteria were selected based on the project specifications provided by our client, Dr. Moody. The designs must pass these feasibility criteria to be considered for production.

- The vehicle must only be composed of K'nex parts.
- Dimension constraints for the K'nex car:
  - Cannot be longer than 12"
  - Cannot be higher than 18"
  - Cannot be wider than the width of one lane
- The vehicle must be self-propelling. Motion can only be a result of the motor. The vehicle can not rely on rubber bands or external forces to produce its motion.

3. Merit Criteria

3.1 Vehicle Mass

We chose mass as a merit criterion for our K'nex car because it impacts velocity. Ideally, the car's frame should be lighter so the motor will not be constrained. Additionally, mass proves a critical factor for this event since the vehicle will have to do more work $(W = F * D)$ against gravity with each round. For this reason, we made this merit criterion worth 40%. The minimum mass for the vehicle to receive a merit score is 500 g, and the maximum mass is 1300 g.

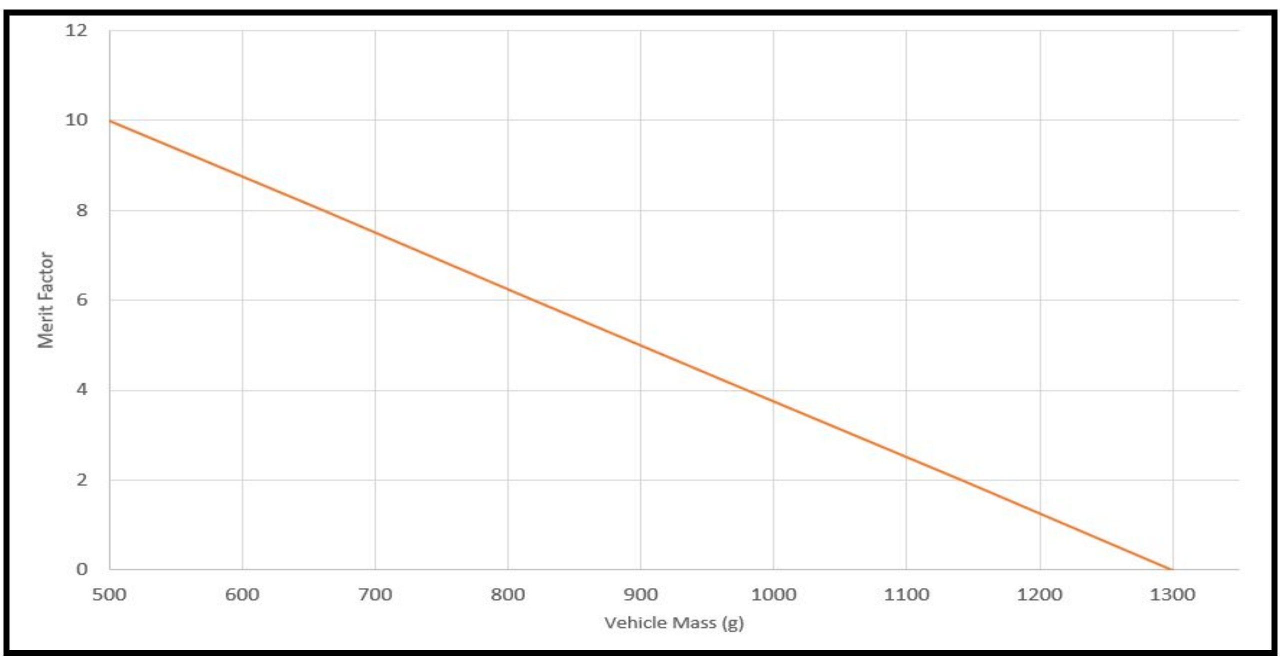

Figure 1: Merit Curve for Vehicle Mass

3.2 Velocity

We chose velocity as a merit criterion for this project since velocity would contribute to the result of the Hill Climber competition. Since each K'nex car will only have 90 seconds to climb the hill, velocity is a quality that will ensure the vehicle can travel the necessary distance within the maximum of 90 seconds. Furthermore, the team with the fastest car in the last round (hill with the largest incline) will be the winner of the Hill Climber. The weight of this merit criteria is 20% because it will ensure the K'nex car competes in the entirety of the event, and may even be the deciding factor in winning the competition.

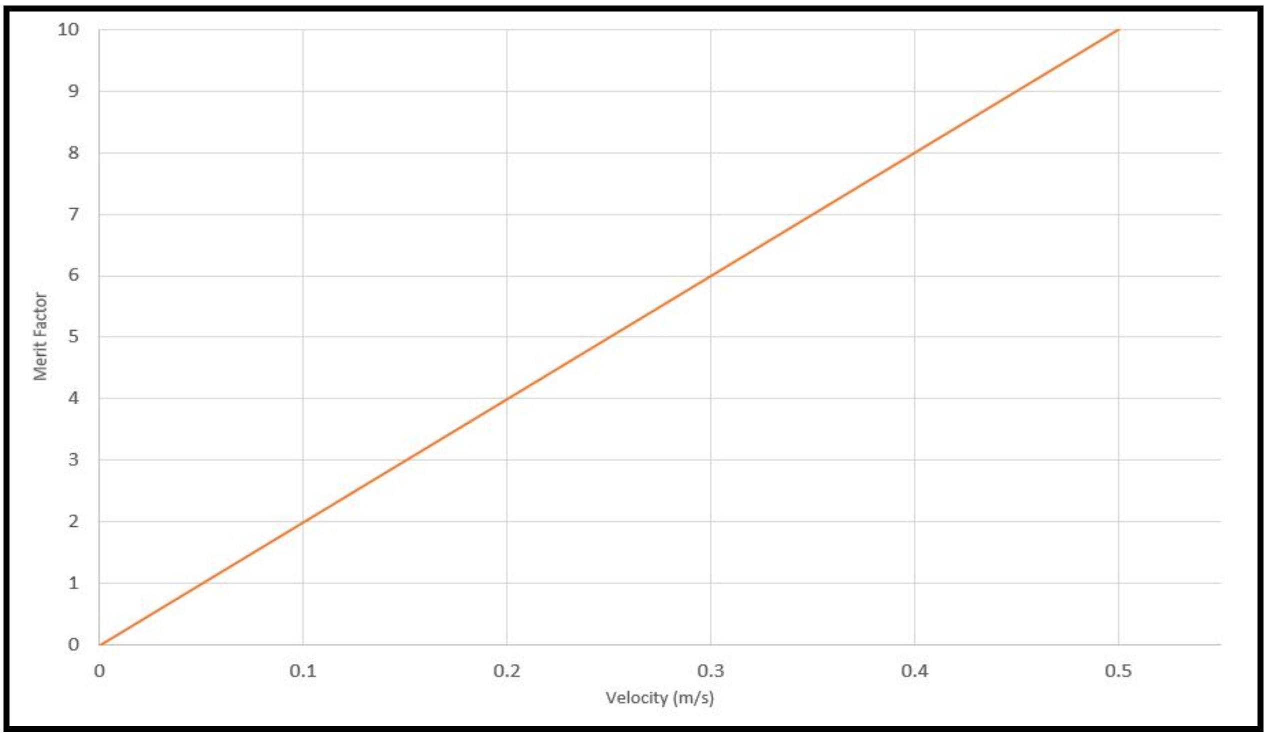

Figure 2: Merit Curve for Velocity

3.3 Gear Ratio

We chose gear ratio as a merit criterion for this project as gear ratio is directly proportional to the torque of the vehicle, which will determine the amount of gravitational force the car can counteract. This characteristic greatly depends upon the diameter of the gears embedded in the vehicle, and their locations. Greater gear ratio means larger torque, which will help our K'nex car to complete the later stages of the competition as the hill becomes steeper. The merit weight for this criteria is 40% not only for its value to the car's performance but also because it accounts for the car's overall design. The formula for gear ratio is show in **Equation 1;** in our case, R_1 is the radius of the gear attached to the motor, and R_2 is the radius of the gear attached to the first gear and each respective wheel. A higher gear ratio is indicative of higher torque, and thus of higher performance in the Hill Climber event. As such, a higher gear ratio will result in an increased merit factor.

$$\text{Gear Ratio} = R_1/R_2$$

Equation 1: Gear Ratio

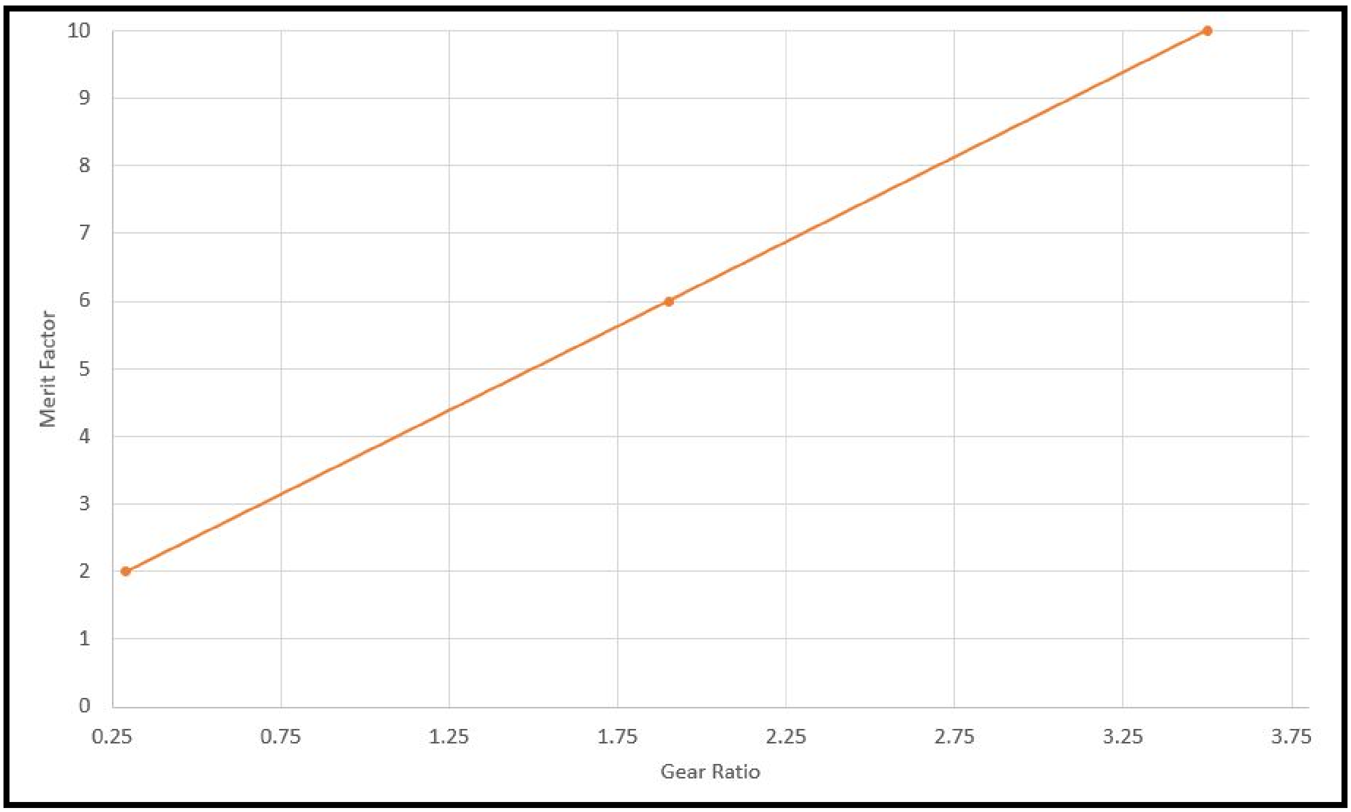

Figure 3: Merit Curve for Gear Ratio

4. Design Alternatives

4.1 Design 1

Design 1 will be a two-wheel drive K'nex car; the design will have a 5.715 cm diameter wheel in the front, and a 12.7 cm diameter wheel in the back. The motor will be placed approximately 7 cm behind the front wheel; a 8.89 cm diameter gear will be connected between the front wheel and the motor. The design will be 30 cm in length, 13 cm in width, and 8 cm in height. The estimated mass for design 1 is 900 g. The estimated gear ratio for design 1 is 0.29 (using gears with 1.27 and 4.45 cm radii) and the estimated speed for this design is 0.31 m/s. All of the estimated dimensions are based on the motor properties and other information provided by our instructor. The advantage of this design is the proximity between the motor and the front wheel, which represents even weight throughout the vehicle. In addition, design 1 have a decent estimate of the velocity, which will make design 1 succeed in meeting the time limit in each round of the hill climber competition. One disadvantage of design 1 is that it has a low gear ratio, which means it will have difficulty climbing the hills with large inclination.

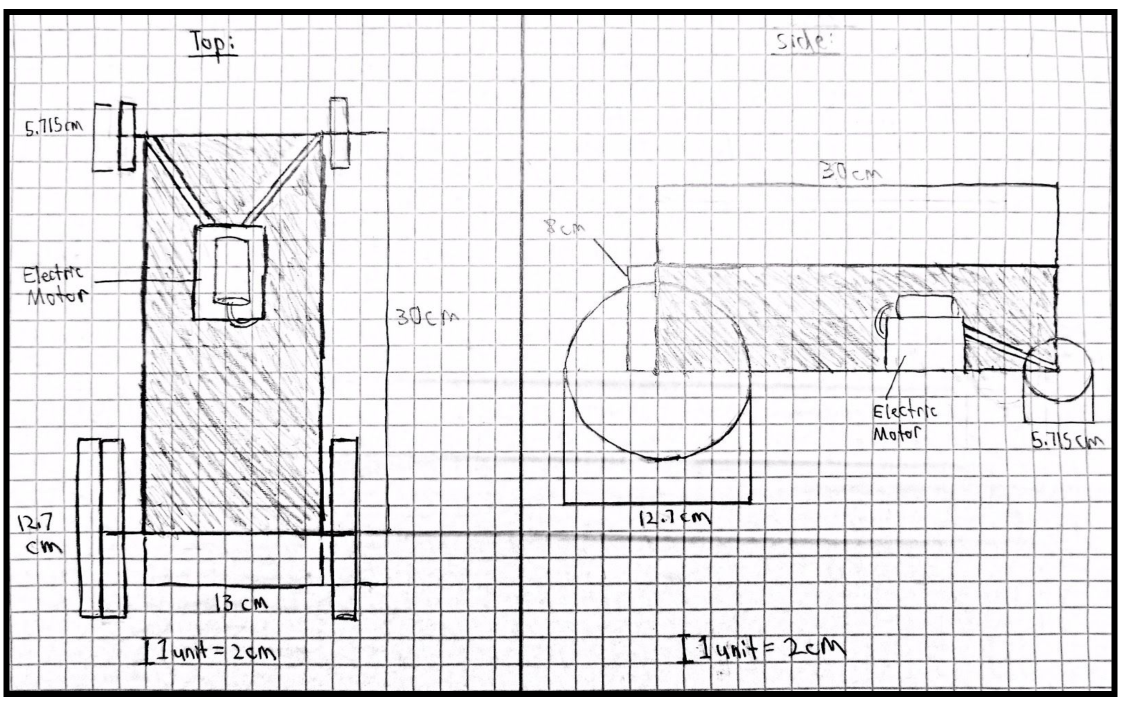

Figure 4: Design 1

4.2 Design 2

Design 2 will be a two-wheel drive K'nex car; the design will have two 12.7 cm diameter wheels in the front and two 4.13 cm diameter wheels in the back. The vehicle will be about 25 cm in length, 10 cm in width, and 18.7 cm in height. The motor will be placed approximately 2 cm behind the front wheels. The estimated mass of this design is 930 g. The estimated speed and gear ratio for design 2 is 0.30 m/s and 2.25 (using gears with 2.8575 and 1.27 cm radii), respectively. All of the estimated dimensions are based on the motor properties and other information provided by our instructor. The advantage of design 2 is that most of the vehicle weight is in the front, which is where the motor is placed; this is beneficial for the hill climber competition because less weight in the back represents more strength against the different inclinations of the hill.

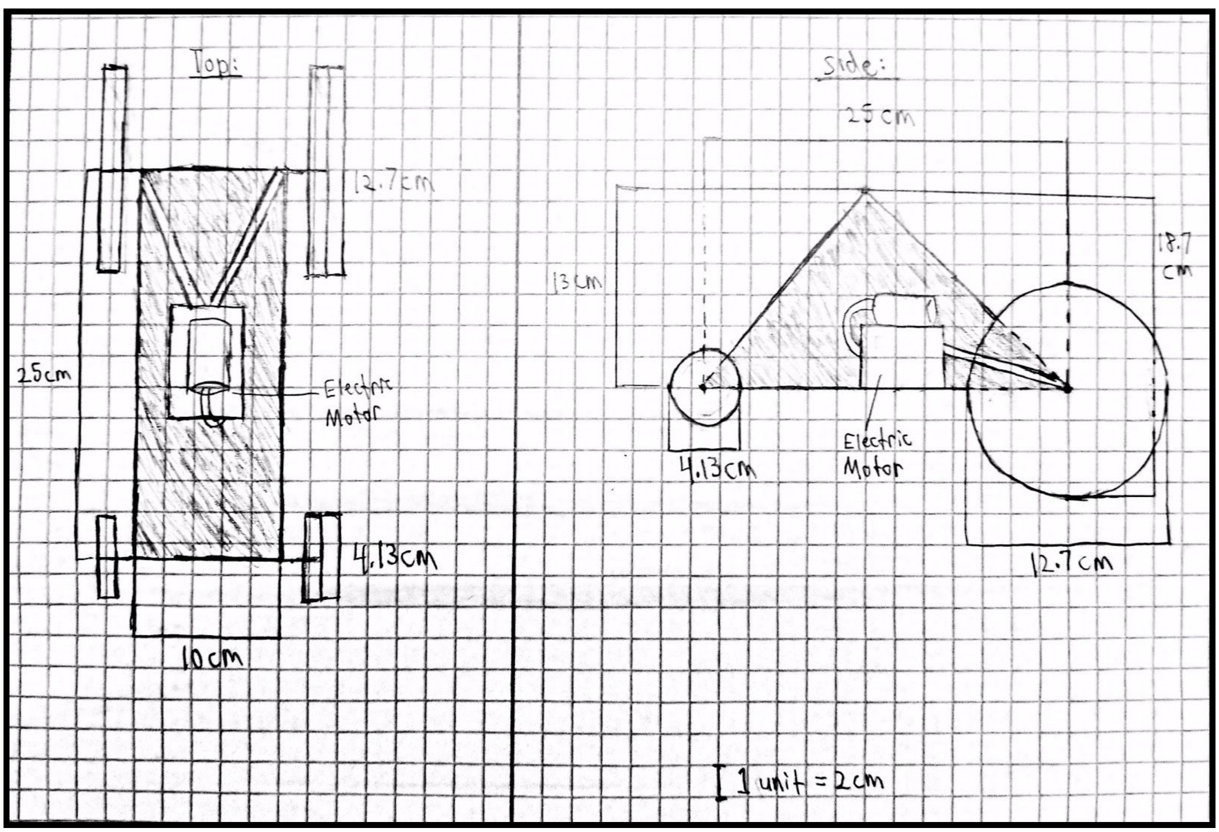

Figure 5: Design 2

4.3 Design 3

Design 3 is a four-wheel drive K'nex car. The design will have two 12.7 cm diameter wheels in the back and two 8.89 cm diameter wheels in the front. An engine will be attached to each of the car's axles, and the car will be approximately 27 cm in length, 14 cm wide, and 15 cm tall. The motors will be placed next to each other in the middle of the car to give the car an evenly distributed weight. The car has an estimated mass of 1200 grams. The estimated speed is about .2m/s, and the estimated gear ratio for design 3 is 3.5 (using gears with 4.445 and 1.27 cm radii). All of the estimated measurements are based on the information provided to us by the professor. The advantage of this design is its high gear ratio. This design is intended to have the highest possible torque of all three designs, and it has an evenly distributed weight due to the positioning of the motors. The bigger wheels in the back allow the vehicle to travel more distance with one rotation of the wheel vs. one rotation of a smaller wheel. One disadvantage of this design is that in correlation to its high gear ratio, it has the lowest estimated speed out of all three designs.

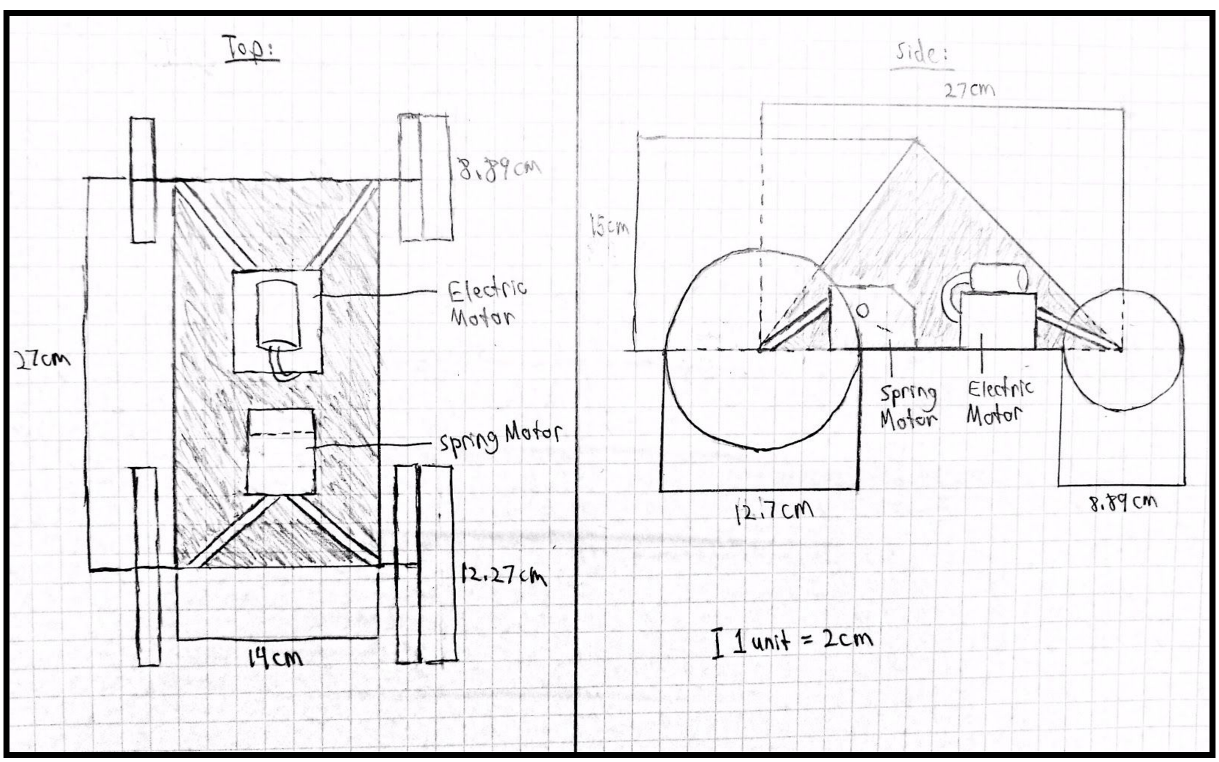

Figure 6: Design 3

5. Feasibility Analysis

All of the designs proposed meet the feasibility criteria for the K'nex car project, as they have all been designed with them in mind. They all meet the required dimensions, and can all be constructed using the given K'nex parts.

Table 2: Feasibility Criteria Analysis

Criterion:	Design 1	Design 2	Design 3
Only composed of K'nex parts.	✔	✔	✔
Cannot be longer than 12"	✔	✔	✔
Cannot be higher than 18'	✔	✔	✔
Cannot be wider than the width of one lane	✔	✔	✔
Does not rely on rubber bands to produce motion	✔	✔	✔

6. Merit Analysis

6.1 Design 1

Design 1 received a overall score of 514. Design 1 is the lightest among all other preliminary designs; also, design 1 has a decent speed, which means that it will succeed in meeting the time limit of each round of the competition. However, design 1 has a low gear ratio, which results in less torque to counteract the gravitational force when climbing the hill.

Table 3: Merit Analysis for Design 1

	Weight (%)	Feature Attribute	Merit Factor	Total Merit
Vehicle Mass	40	900 g	5	200
Velocity	20	0.31 m/s	6.2	124
Gear ratio	40	0.29	2.05	82
Total	100			**406**

6.2 Design 2

Design 2 received a overall score of 574. Design 2 distributes adequate performance across all three of the merit criteria. This design has the second lowest mass, the second highest velocity, and the second highest gear ratio.

Table 4: Merit Analysis for Design 2

	Weight (%)	Feature Attribute	Merit Factor	Total Merit
Vehicle Mass	40	930 g	4.8	186
Velocity	20	0.30 m/s	5.8	116
Gear ratio	40	2.25	6.8	272
Total	100			**574**

6.3 Design 3

Design 3 received a total score of 532. This design has the highest gear ratio of all three designs, but it also has the lowest velocity. Design three is also the heaviest of all three designs. This car is intentionally designed to have high torque, referring to its high gear ratio; however, the mass is proportional to the increase in gear ratio.

Table 5: Merit Analysis for Design 3

	Weight (%)	Feature Attribute	Merit Factor	Total Merit
Vehicle Mass	40	1200 g	1.3	52
Velocity	20	0.20 m/s	4	80
Gear ratio	40	3.5	10	400
Total	100			**532**

7. Design Recommendation

Design 1 has the lowest merit score out of all three designs. Although design 1 wass the lightest and fastest design, its low torque, proportionate low gear ratio, made vehicle it difficult for the vehicle to climb hills with higher inclinations. Design 3 had the highest gear ratio, but its low speed and large mass would impede it from climbing a hill within the permitted time. Finally, Design 2 had the highest merit score. We recommended this design for the Hill Climber event for its efficient balance between velocity and gear ratio. While this design did not score the highest in either of these categories, this car demonstrated optimal performance across the criteria.

Table 6: Total Merit Score for all Designs

	Design 1	Design 2	Design 3
Total Merit	406	574	532

8. Testing Plan

Our team will conduct the following tests to evaluate the performance of our vehicle prior to the competition:

8.1 Test 1

In order to test the finished design, we will have the car drive over a track at varying inclinations. This will allow us to predict the car's performance during the actual rounds of the Hill Climber event.

8.2 Test 2

We will conduct a test over varying intervals of time and distance to calculate velocity. With this test, we can ensure the car is at an optimal velocity to satisfy the merit criteria, and to succeed in the race.

8.3 Test 3

We will examine how much a stronger pull of gravity will affect the car's velocity. The test will consist of measuring the car's velocity during trials in which the vehicle carries different masses. These results will further illustrate how the strength of the engine will pull the vehicle up the increasingly inclined planes.

9. Summary

The purpose of this project is to introduce fundamental engineering concepts to the students by giving them the opportunity to work with a client, just like in a professional situation. The objective of the project is to build a K'nex car that meets the required project specifications and performs the best at the Hill Climbing event assigned by our client, Dr. Moody. The car must follow all rules for its assigned event; it must also meet the feasibility criteria that are based on the project specification assigned by our client.

We proposed three separate preliminary designs, and, each has their strengths and weaknesses. We will recommend one of these designs to build out of the given materials to compete in the Hill Climber event.

All of the cars were adequately designed according to the feasibility criteria, but had different scores when evaluated through the merit criteria. Design 1 had a score of 406, being the lightest design with the highest velocity as well. However, it has very little torque and

would not be suited to climb a hill. Design 2 achieved a score of 574, with proficient scores in all three merit criteria. It had the second lowest weight, second highest velocity, and second highest gear ratio. Lastly, Design 3 had the highest mass and consequently the highest gear ratio, but ended having the lowest velocity. It received a 532 total merit score. We recommend design 2 for its high merit score, and will conduct three different tests for our merit criteria before the final competition.