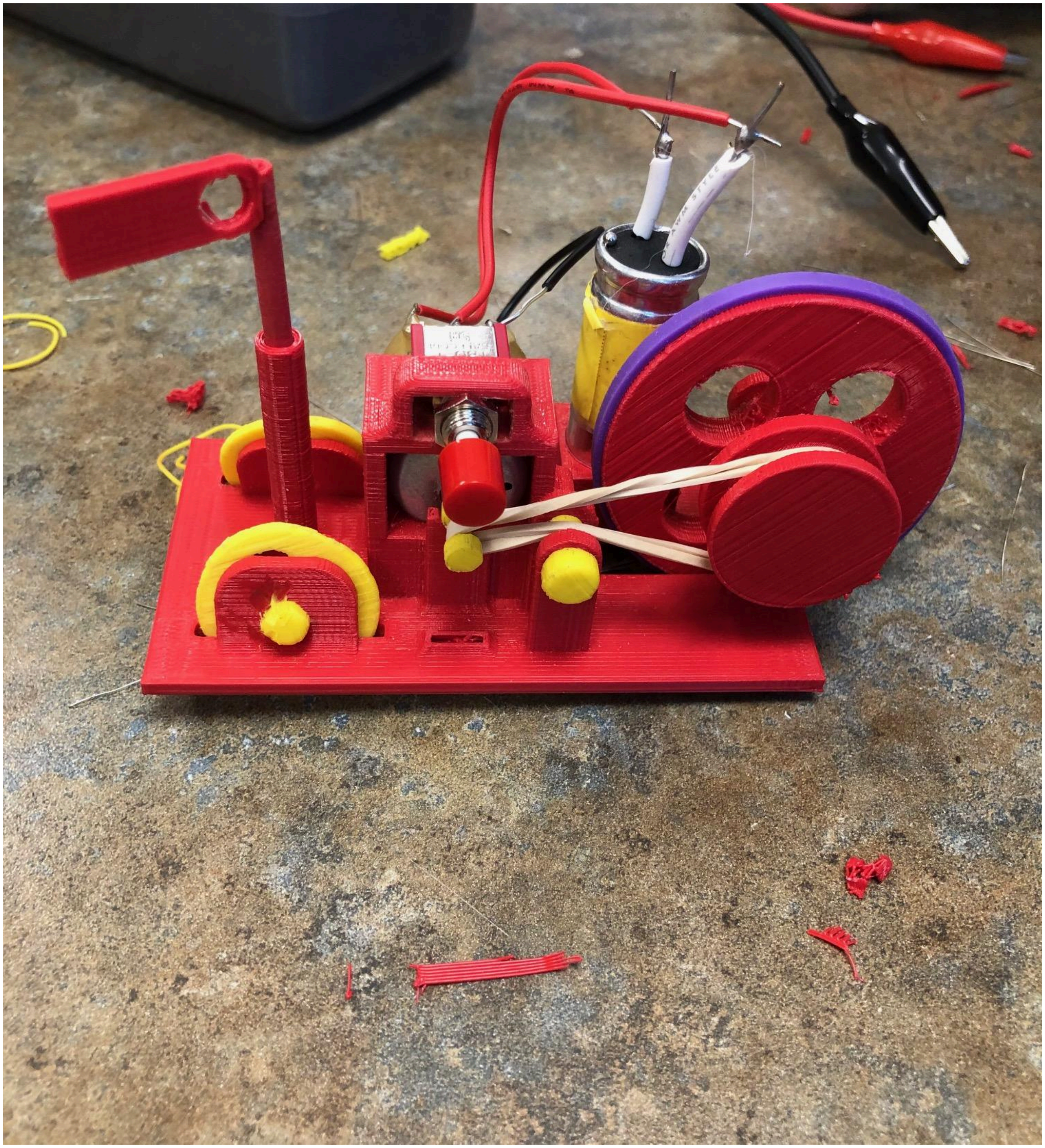
Super Capacitor Powered Car



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Objectives:

- Research, design, build a car powered by a super capacitor that will travel the length of a basketball court.
- Identify and document variables affecting how far the car will travel.
- Document the research and calculations used.

Procedure:

1. We grabbed the materials:
    - 20 farad 2.7 volt super capacitor
    - 29DCM22 3 volt DC motor
    - SPDT push on/off switch
    - Computer with Inventor
    - PLA
    - Solder
    - Wire
    - Rubber Bands
2. We first discussed and theorized the best way to construct a car to successfully traverse the length of the basketball court.
3. Some variables that we discussed were amount of wheels(3 or 4) which would affect stability and traction, two wheel or all wheel drive which would affect the car's power, shape of the platform which would affect drag, usage of pulleys or gears which would affect the force pushing the car forward and the total energy lost, the ratios of the pulleys or gears, and whether to have the motor wheels smaller or bigger to figure out how to best conserve the motors energy and gain the most distance.
4. We decided on four wheels with a gear ratio of 4:1 for our car because we believed it would be the most effective in the situation given.

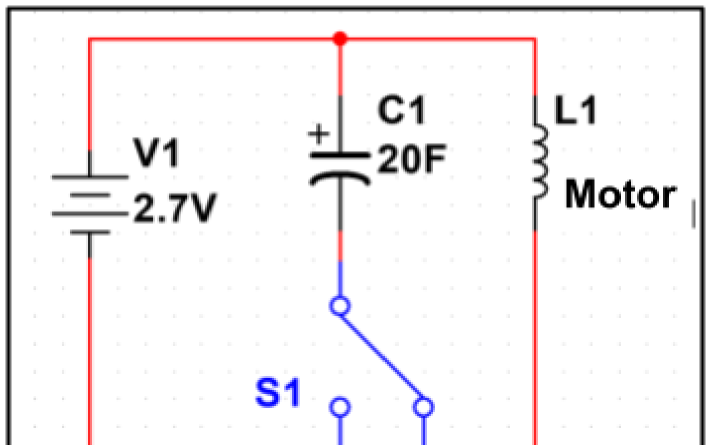


Figure 1

5. We then constructed figure 1 to test the circuit that we will be using for the car on a breadboard.
6. Before we started testing the circuit we hooked the dc motor, an ammeter, and a power supply all in series, we set the power supply to various voltages and measured the amperes at their respective voltages, this is shown in the table below.

volts (v)	amps (mA)	resistance	Capacitance (F)	Tau (seconds)	Capacitor discharge time (seconds)	Rpm
3.0	260.0	11.5	20.0	230.8	1153.8	11000.0
2.7	250.0	10.8	20.0	216.0	1080.0	9900.0
2.1	228.0	9.2	20.0	184.2	921.1	7700.0

Table 1

7. We then used the voltage values and the amperage values to find the resistance the motor was giving off by dividing the respective voltages by their respective amperages to get a range of 9 to 12 ohms. Now that we had a general idea of what the resistance of the motor was, we could now take those resistance values to find the tau or the time constant of the capacitor and motor. We found the time constant of the capacitor when discharging each different resistance value by multiplying each resistor value by the capacitance value 20 farads to get a range of 184 seconds to 230 seconds.
8. Since a capacitor takes 5 time constants to discharge we multiplied the lowest tau value we recorded, to prepare for the worst, by five to get 921 seconds how long the capacitor will take to discharge.
9. We set up a phone as a stopwatch and charged the capacitor to full storage, then we timed how long the motor spun until the capacitor ran out of enough energy to spin it. The motor successfully spun at decreasing RPM for 4 minutes and 44 seconds. We recorded the data in table 2 below in comparison to our calculations.
10. We then conducted the same experiment again, but with a voltmeter hooked up to the leads of our super capacitor. We then learned that the motor stopped spinning once there were about 0.15 volts left in the capacitor.

Table 2	Discharge time (seconds)
Practice	284
Theory	921

11. We looked up the specs sheet for the motor by googling the type of motor we had, we found the motor on walmart's website and in the description was a link to a business directory. In the business directory we found a link to the company who produced the motor, R.S.R. Electronics Inc.'s website that gave us the specks of the motor. On the specks we found that the motor spins at 11000 rpm at 3 volts. Using this proportion, we figured out the motor's rpm at specific voltage values and recorded the data in table 1.
12. We then multiplied the 921 seconds of discharge by the associated rpm of 7700 and the circumference of the wheel which we found by multiplying the diameter of the wheel(2 in) by pi to get 6.28 in which in total results in 44535876 in. (NOTE we did not account for forces lost or the declining capacitor charge, we later found how to factor in power loss)
13. While some people were doing the data portion the other people were designing the body and the wheels for the car. They were also designing the gears so they could be used with the capacitor to get the outcome that we wanted.
14. We decided to go with four wheels and two gears with a ratio of 4:1, the gears seemed to be the best option to get the desired outcome.
15. We also had the design people make the base have enough space to fit the circuitry into the car so we were able to make it run smoothly as the proportions of the parts were measured so we could fit them in perfectly.
16. The way they fit in would help with the performance and could prevent disaster like the parts falling out of the car or the parts not being able to function properly. The photos to show our parts can be found in the gallery.

17. Once our car was mostly printed, everything except the back axle and back wheels, we began to to sand down sections of the body the electronic components into their holders, sanded the sections of the axles that clipped to the body of the car so they could clip to the body, and sanded the motor gear axle. Once every thing that was printed was sanded to the desired size we were able to test the cars ability to drive
18. When we tested the car's ability to drive we found that the motor was not strong enough to spin the driving gear meaning the motor could not spin the car wheels. After some time of the motor trying to spin the driving gear the motor broke the inside of the gear letting the motor axle spin freely on the motor gear.
19. We then tried the fail safe to see if that would help, but the fail safe was useless if the motor axle could spin freely off the gear.
20. After some advice from our instructor, our group decided to redesign the car after a lot of discussing.
21. We researched our previous variables that could affect the car distance and brainstormed new variables to research as well. We then researched the variables below.
    - Number of wheels
    - Two wheel or all wheel drive
    - Cutoff frequency
    - Shape of the car body and wheelbase
    - Pulleys or gears
    - The ratio of the pulley or gear
    - Tension of the rubber band
    - The camber of the wheels
    - Rpms of the motor
    - How long the motor would run
22. When researching what number of wheels would be best for our car. We found on source 8 that 3 wheels would have less rolling resistance due to less wheels being on the ground and less points creating less rolling resistance, we found no direct equation that related rolling resistance to the number of wheels. We thought that less rolling resistance would be more beneficial because the less resistance we have the easier it is for our motor run.
23. While researching the effect of two wheel or all wheel drive we were unable to discover a source that could confirm whether all wheel or 2 well drive was more beneficial when it came to our skale. We decided to go with 2 wheel drive because it would be more simplistic and less things could go wrong.
24. Looking up how cut off frequency would affect our car by using reference 1, from that source I realized that since we were using dc cutoff frequency would have no effect on the car since DC has a frequency of 0.
25. We decided to go with pulleys rather than gears this time around because on our last car our motor was not strong enough to move the gears due to the motor having little torque. While it may have been possible to do gears again we didn’t want to risk it again.
26. We were able to research the ratio of the pulleys or gears using the equation $D = C(Rx)$ x = gear ration, r = motor rotations. We also figured out whether to have the motor wheels smaller or bigger by using the equation, $D = Rc$, r = wheel rotations we got these equations by doing math based off of the video contained in reference 6.

27. Another thing we researched was the tension of the rubber band and we used the equation -F = T + G. T=tension, G=gravity and F=force. We got this equation from the link in reference 5.
28. We also found that mass impacts the total distance the car travels by the equation D = ½(F/m)t^2.We got this equation from simplifying equations contained in reference 7.
29. Since the motor was the same we were able to use all of our calculations regarding rpm we calculated from the last car design as shown in steps .
30. Research was done on how the camber on the wheels affected the stability of the car as we didnt want our car to tilt and fall over when it moved. We found out that we wanted a negative camber making it look like the wheels splayed further from the frame of the car as they got closer to the ground creating a triangle base holding up the frame. If we had used zero camber our car could have been less stable and if we had used a positive camber the car would be easily prone to turning or falling over. We also made sure not to use too much camber so that the wheels still turned when the car moved forward, in our research we found that in general, wheelchairs with high camber only use up to 15 degrees because after that point the only point of camber is stability while cornering at high speeds, and we had no need for turning.
31. Once the research was done we began to design our car. In the redesign we made the call a lot smaller and made a lot of changes that can be shown in the gallery.
32. We got the design printer ready and started the print.
33. Once we had the car we began to sand and adjust the parts to get them to fit together. In this process we accidentally dropped the car breaking one of the parts.
34. We then reprinted the car.
35. Afterward we did the math to see if our car could go the distance. To calculate the total distance our car would travel, we first took the worst case starting voltage of 2.1 volts and then repeatedly took ⅔ from the voltage to get the voltages at the five time constants logged in the table below. We then used the proportion of 11000 rpm at 3 volts to get the rpm for each time constant. We then multiplied each of these by the 3.07 minute for each constant to get the total rotations for each constant. Furthermore, we divided each of these by our wheel ratio of 7.5 to get the rotations per constant of the wheels since the wheels are 10 times bigger than our mechanism. Finally, we added these numbers together, multiplied the answer by the 6.28 inch circumference of the wheels, and converted that answer to feet to get our final answer of 51462.1, not accounting for loss of energy. We logged the data from each step below in table 3.

	Voltages(v)	Rpm at v	Rotations	Wheel rotations	Total rotations	Distance (ft)
1	2.1	7700	23639	3151.9	8194.6	51462.1
2	1.4	5133	15759	2101.2		
3	0.93	3410	10468	1395.7		
4	0.62	2273	6979	930.5		
5	0.41	1503	4615	615.3		

Table 3-With power loss

36. We then did the same math again, but with the 56.8 sec time constant we got through our physical experimentation and logged the data in table 4.

	Voltages(v)	Rpm at v	Rotations	Wheel rotations	Total rotations	Distance (ft)
1	2.1	7700	7291.9	972.3	2527.7	15873.9
2	1.4	5133	4861.0	648.1		
3	0.93	3410	3229.3	430.6		
4	0.62	2273	2152.5	287.0		
5	0.41	1503	1423.3	189.8		

Table 4-With power loss

37. We made some last minute adjustments, including soldering together our circuit and filing and melting the clips on our frame to make a better fit with the wheel.
38. We went to the gym for our car's final test, and it only went about seven feet due to the fact that our motor pulley wheel (part 2 in revised version) snapped after only a few seconds.

Discussion:

Problem: We were unable to figure out the time it took for the capacitor to charge.
Troubleshooting: We did some extra testing and then decided to ask the instructor for help as we were stuck and other classmates were stuck on the same thing.
Solution: The instructor showed us that the capacitor would charge all the way once the current on the power generator reached or was close to zero as the current would keep decreasing by two thirds until it hit zero which meant it was fully charged.
Problem: When the capacitor was connected to the 3v DC motor, the capacitor only powered the 3v motor for a significantly less time.
Troubleshooting: first we checked our calculation to see if we were right, then we went to our instructor to get some clarification
Solution: With the help of our instructor we determined that our calculations were based off of relatively perfect circumstances meaning that in real life parts are imperfect which can lead to power loss as we experienced. Another factor is that the motor only runs at a certain range of voltage meaning that the motor will turn off at a certain voltage, and due to the fact that the capacitor losses voltage as it discharges that means that eventually the capacitor will reach a low enough voltage where it will no longer be able to power the motor but will continue discharge making it appear that it stopped discharging earlier than it did.
Problem: Our car was unable to spin the gear attached to the motor due to it being too large and the gears creating too much friction and our fail safe did not work either.
Troubleshooting: We brainstormed how we could fix the gear to get the car working again and thought about redesigning the car.
Solution: We redesigned a new car based off of past mistakes from our past car and new research in factors affecting the car.
Problem: Our clip system was very tight and required a lot of filing and melting of pla to fit the wheel correctly.
Troubleshooting: We thought about how better to design our system so the wheel would clip in better.

Solution: We realized that although we would not have time to change our design, we could make the clips on the side instead of on top to make it fit better, as well as pop out less

Conclusion:

1. We researched, designed, and built a car powered by a super capacitor that is capable of crossing a basketball court in theory. As stated in step 21 We did research and thought about all the possible variables that could affect the distance of our car. We then started remodeling the car in autodesk inventor and printed it out as stated in step 31. We also did the math as shown in tables 3 and 4 to figure out that even at our worst starting voltage of 2.1 v and the corresponding 7700 rpm our car can make it across the gym in theory and based on actual capacitor discharge times by using the time constants of 3.07 minutes and 56.8 seconds to calculate to motor and wheel's total rotations at different voltages, then finding the total motor rotations of 8194.6 and 2527.7. Multiplying these numbers by the wheel's circumference to get the distances of 51462.1 feet and 15873.9 feet. However, our car only went about 7 feet in our actual test because part number 2 in our revised schematic broke and derailed our entire drive train.
2. We documented variables that will affect how far and fast the car will travel in steps 26 - 28 when we identified variables in our car's construction that could affect the car's speed and distance traveled by using math, such as when we found the formula $D = \frac{1}{2}(F/m)t^2$ where m = mass and were able to conclude that mass of the car did affect distance.
3. We did research from our notes taken in related classes, as well as found the specs for the motor on a website called electronics express, the website for the company R.S.R. Electronics Inc. which is the manufacturer of the motor and was found through Walmart online shopping. We used calculations and formulas based on our notes as shown in step 7 when we used the voltage and current to calculate the internal resistance of the motor to be 9 to 12 Ω and then multiplied that by the capacitance of 20 h to get a time constant of 184 seconds to 230 seconds. We then multiplied that by five to get the total discharge time of the capacitor to be 1153.8 seconds to 921.1 seconds. We also used www.khanacademy.org to find the equation for circumference to be $C=\pi d$.

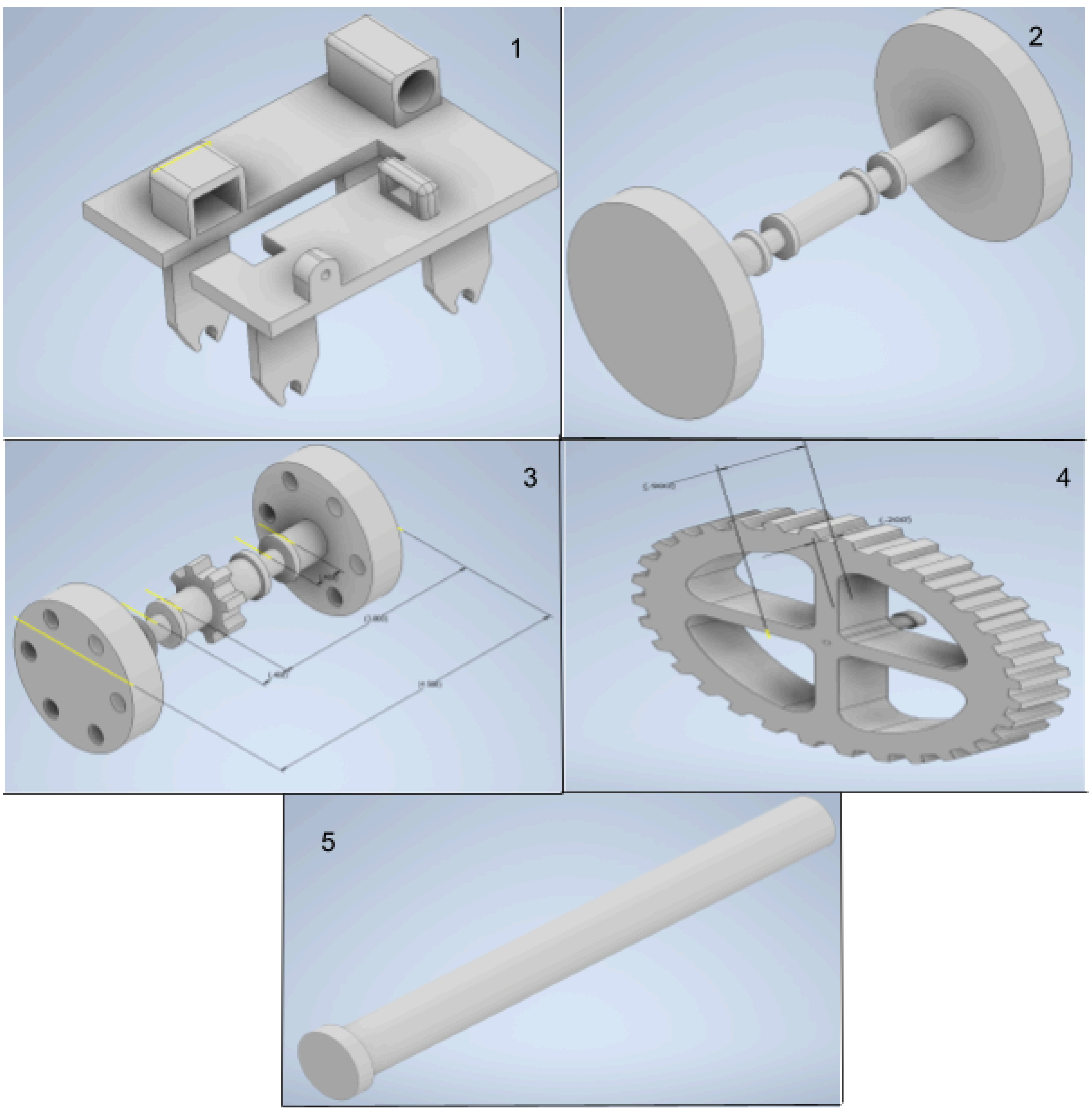
References:

1. https://www.electrical4u.com/cutoff-frequency/ Used in step 24
2. https://www.walmart.com/pac?id=fb929144-cc76-4b0d-a1bd-8497d297379e&quantity=1&careplanOfferId=&shipMethodDefaultRule=SHIP_RULE_1 Used in step 11 to find business directory
3. https://www.dnb.com/business-directory/company-profiles.rsr_electronics_inc.f29192e661bc05ecec27a95b30c9a53b.html Used in step 11 to find manufactiures of the motor's manufacturer
4. https://www.elexp.com/29dcm22motor-dc-3v-w-wire-6.html Used in step 11 to find motor specs

5. https://sciencing.com/calculate-pulley-systems-6529707.html Used in in step 27 to find pulley tension
6. https://www.youtube.com/watch?v=TRv-p5v2ckY Used in step 35 and 36 to realize the relationship between gear ratio and distance, as well as the relationship between wheel size and distance
7. https://www.youtube.com/watch?v=TjxUEwMjmvc Used in step 28 to realize the relationship between mass and distance
8. https://www.torquenews.com/1080/3-wheeled-cars-will-always-be-cool#:~:text=A%20three%20wheeled%20automobile%20has,to%20be%20aerodynamic%20as%20well. Used in step 22 to research rolling resistance.
9. https://www.motioncomposites.com/en_us/community/blog/tips-and-tricks/camber-degrees-of-performance Used in step 30 to find the optimal camber of the wheels for our car.

Gallery:

First build of the car:Body: 1, Inactive wheels: 2, Active wheels: 3, Motor gear: 4, Gear shaft: 5



Revised version of the car: Body: 1, Motor pulley wheel: 2, Roller axle: 3, Roller: 4, Drive wheel: 5, Rear wheels: 6, Rear axles: 7.