Development of Design

(mention always the names of people you took ideas from!

- **Discuss the evolution of your design. How did your group come up with the final design?**

Our car design had undergone numerous revisions in the transition from paper sketch to finished product. The first major idea we formulated was to cut two halves out of a thick Styrofoam and encase the axles, motor, gears, and batteries within. It was dubbed "The Brick" (Figure 1.1). The major motivation for this design was that we perceived it to be easier than cutting a base and mounting the mechanisms on that. Amid concerns that such a flat-faced, unaerodynamic design would prove disadvantageous, we scrapped the brick idea; the Styrofoam, however, was not completely dropped. We carved a smaller box of Styrofoam and pressed the motor and gearbox tightly into it, speculating that such a casement for the motor would absorb its shock and vibrations. Our largest concern here was that it would be easier to remove and modify the gearbox, during the transition between racing and pulling competitions, if it was simply placed inside the Styrofoam. This was all done the first day. Unfortunately, when our group reconvened the next week, we discovered our box had been ransacked, and our casing was gone – gearbox, motor, and all.

Rather than repeat the previous week, we decided to device an entirely new design plan. Most of the other groups were doing calculations for an optimal gear ratio for reaching peak power. They were stuck in one gear during the race and had to find the right trade-off between torque and speed. What if we could change our gears during the race itself, starting from a high ratio with much torque and transitioning to a low ratio with high speed? We could theoretically achieve a constant peak power. How was this to be done?

What we decided to do was do away with traditional "gears" altogether, and opt instead for a cone that would provide a vast range of gear ratios. It would be attached to the axle itself, and a string from the gear box would wrap around it to transfer movement. This presented us with an entirely new challenge: how to find a cone of adequate volume that could also grab the string. At first, we considered objects that were already cone-shaped, such as the cap to a bottle of mouthwash. Nothing we found, however, matched our ideal dimensions – it should have a large base and a tip that is nearly radius of the axle where it ends. Thus, we needed to build it ourselves. We shaved a large conic shape out of Styrofoam and cut off the top two inches. Next, we wrapped it in sandpaper for better grip. This was glued onto the axle. For the speed competition, it was necessary for us to use a large radius on the bar attached to the gearbox. At first, we merely coated the bar in tape, but this proved insufficient. For maximum radius, we glued three medium-sized wheels together and inserted them onto the bar. The string was attached to this and wrapped about the cone. This completed our transmission device.

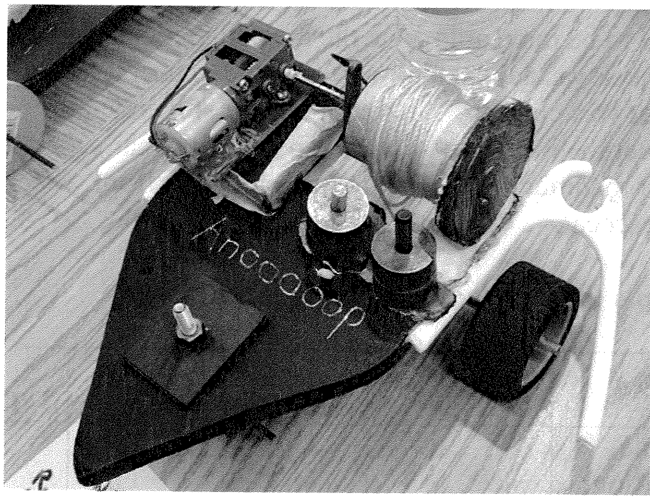
When we were given a $25 budget, we immediately decided that the most important thing we needed to buy were bearings, with wheels secondary. These ball bearings were glued into holes that we drilled in a stiff board material; two of these structures, one on either side of the underside of the car, held the axle in place. The wheels – coated in soft rubber for friction – were glued onto the ends of the axle.

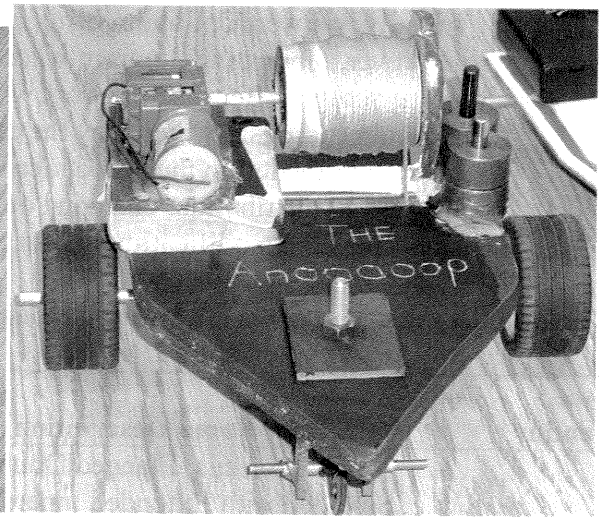
On the other end of the car's belly was a single wheel, made of plastic to reduce friction. On a normal car, the front and rear axles have to be exactly parallel – or the back wheel, if using a single wheel, has to be exactly parallel to the front wheels – if the car is to go straight. This is often a trial-and-error process, and the axles have to be glued, torn off, and re-glued many times before balance is achieved. To avoid this process, we created a back wheel whose position is entirely adjustable. We drilled a hole in two identical pieces of board, and through the car's poster-board base itself, and put one on either face of the car, with a screw through them to hold the structure together, and a nut twisted onto the top end to keep it tight. On the bottom board, we glued two more, longer and thinner pieces of board parallel to each other and perpendicular to the base. The back wheel's axle was held tightly by holes in these two pieces, and the wheel itself – on the axle – was allowed to spin freely. Thus, by loosening the nut on the top, we could rotate the back wheel in any direction.

Finally, the car's base itself was made by epoxying two pieces of poster board together, black sides facing outward for aesthetic purposes. We shaved the sides around the back wheel to create a triangular shape, but this was also purely dictated by aesthetics. Four weights were glued to the front-right end of the vehicle, for two reasons – to counter the weight on the other side, which was provided by the gearbox and battery case, and to provide more force on the wheels to maximize our pulling capability.

- **What was your project plan/schedule?**
  - Our initial design plan was to start building. The first day we toyed around with different ideas (previously discussed) and tried to come up with an overall concept. At this point there were so many variable regarding gears and calculations that we felt it was best we come up with the overall concept and then modify single aspects of it to achieve the desired gear ratio(s). After we came up with our design (a three wheeled car with a semi-continuously variable transmission) we started doing some calculations to get a better idea of the size the cone and drive axel. Once we did some rough calculations, we started to build. First, we cut out the base then constructed our gearbox/motor/battery assembly. Then worked on constraining the axel and mounting the cone on the axel. Finally, we constructed out moveable front wheel and started testing. We immediately realized that our calculations were a little off (our car was ~~way to slow) and decided to~~ make the drum on the output of the gearbox considerably larger. After this change was made, we tested

different wrapping techniques on the cone as well as different positions of the adjustable wheel.





Manufacturing Process

- **What went well in your manufacturing process?**
  - I believe our manufacturing process went very smoothly when compared to other groups. For example, many groups were shearing gears and breaking various other parts, which in turn caused them to change their whole design completely. Other groups experienced problems mounting the motor to the gearbox in such a way that it minimized friction, yet maximized efficiency and adjustability. These problems did not come up during our manufacturing process. I believe this was due to the quality of the overall design of the car. Everything was easily adjustable. Our gearbox could be separated from the motor and easily adjusted. The gearbox and motor assemble was also easy to remove from the car, for it was mounted to the top of the battery housing which snapped on. These aspects of our car made it easy to fix one problem of the car without disassembling the car entirely. One problem we did have was the selection of the string that connected the gearbox to the cone. This string needed to be strong enough to withstand a decent amount of force, thin enough so it did not change the radius of the cone too much when it was wrapped, and the fibers of the thread had to not pull apart after multiple trials. First we tried regular cotton twine. This was too thick and also broke. Then we tried a fishing line type tread. This held its shape too well and often unwound itself and jumped to different parts for the cone. Finally we settled on a nylon woven thread. It was is a bit thick but it didn't come apart or break so we had to use it.

- **What changes were made to your design? Why?**
  - Changes have been previously discussed.

- **Did your manufacturing plan change? Why?**
  - Our manufacturing plan did not change for the majority of the building process. One significant thing that did change was the way we attached the front wheel to the car. Initially, we were not planning to make the front wheel of the car adjustable. However, fabricating the front wheel to be moveable gave the car a higher chance of going straight. Because the front wheel was adjustable, we were able to turn it left or right depending on which way the car was curving. Although our car still ended up curving to the left in the speed race competition due to other aspects of the car such as the weight distribution, changing our manufacturing plan for attaching the front wheel was a positive modification for our racecar.

Include the parts you ordered, and the receipts (if you made your own purchases).

Vendor	Item Name/Description	part/order #	quantity	unit price	Total
McMaster-Car	Ball Bearings/ Flanged Double Shielded with Extended Inner Ring	*57155K331*	*2*	*$7.45*	*$14.90*
Pitsco	Lx Wheel (2 pack) A Pitsco Exclusive	*W30845*	*1*	*$1.00*	*$1.00*

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Analysis of Performance

- **Include your calculated predictions of time to complete 15m and maximum pull force and explain the methodology used.**

  - Because we used a variable transmission, we did not do the calculation of the time it would take to complete 15m. This calculation depended on the wrapping of the string and this changed every race. Even if we calculated for constant peak power, human error would have caused this calculation to grossly inaccurate. We figured this would not be an effective usage of our limited time. Instead we calculated the gear ratio that provided the maximum torque at the wheel without slipping (calculations shown below). We knew this would correspond to the maximum radius of the cone. We also knew that when the car had achieved top speed, little torque would be needed. Thus, we wanted a gear ratio that was close to one (the angular velocities of the tires were equal to the angular velocity of the motor output shaft). With that information, we constructed a cone that could achieve our maximum gear ratio and our minimum gear ratio.

$$M_o k = F_f r$$

$$M_o k = F_n \mu r$$

$$(.02728)k = (2.33611)(.84)(2)$$

$$k = 143.866$$

$$k * 2 = 287.7$$

Using the coefficient of friction for rubber on rubber, we were able to determine that the maximum gear ratio we wanted to achieve was 287.7.

- **Discuss the accuracy of your predicted results against the performance. What are possible sources or error and what assumptions were made in your calculation?**
  - I don't believe there were many errors in our calculations (seeing as Anoop looked them over). On the other hand, I believe the sources of error came in actually achieving the gear rations we wanted. It proved to be a difficult task to figure out the wrapping technique that would achieve the fastest time. Although our car did not perform to well in competition, we were able to achieve time in the low 5's and high 4's during trial runs. The times varied quite a bit depending on how the string was wrapped, however, by the end of testing our car was consistently running low times.

Table of Results from Competition Day

	First Trial	Second Trial
Speed Race	Did not cross the finish line	Did not cross the finish line
Pulling Competition	8.5 oz	---------
Tug-of-War	Lost in the first round	---------

- **What went well during the competition?**
  - The competition overall did not go too well for us; however, we were definitely using the MacGyver method throughout the duration of the competition. Using the MacGyver method, we attempted to temporarily fix small problems with our car, such as problems with our gear box output shaft spinning independently from the drum it was attached to. One aspect that went very well was the speed of our car in the speed race. Although our car crashed towards the end of the race track, the speed of the car was very fast. The string-cone gear system effectively made the car go really fast.

- **What did not go as expected?**
  - A couple things did not go as we expected for our car on the competition day. First of all, when we ran the first trial of the speed race, our car went fairly straight for most of the track and then unexpectedly curved to the left and crashed, unfortunately about a foot before the finish line. We did not expect this, since we had pre-adjusted the position of the front wheel beforehand so that the car would run straight on the day of the race. Before our second trial, we again readjusted the front wheel and tested the car out several times to make sure it went straight; our car went fairly straight on these several practice runs. However, when we ran it for the second trial

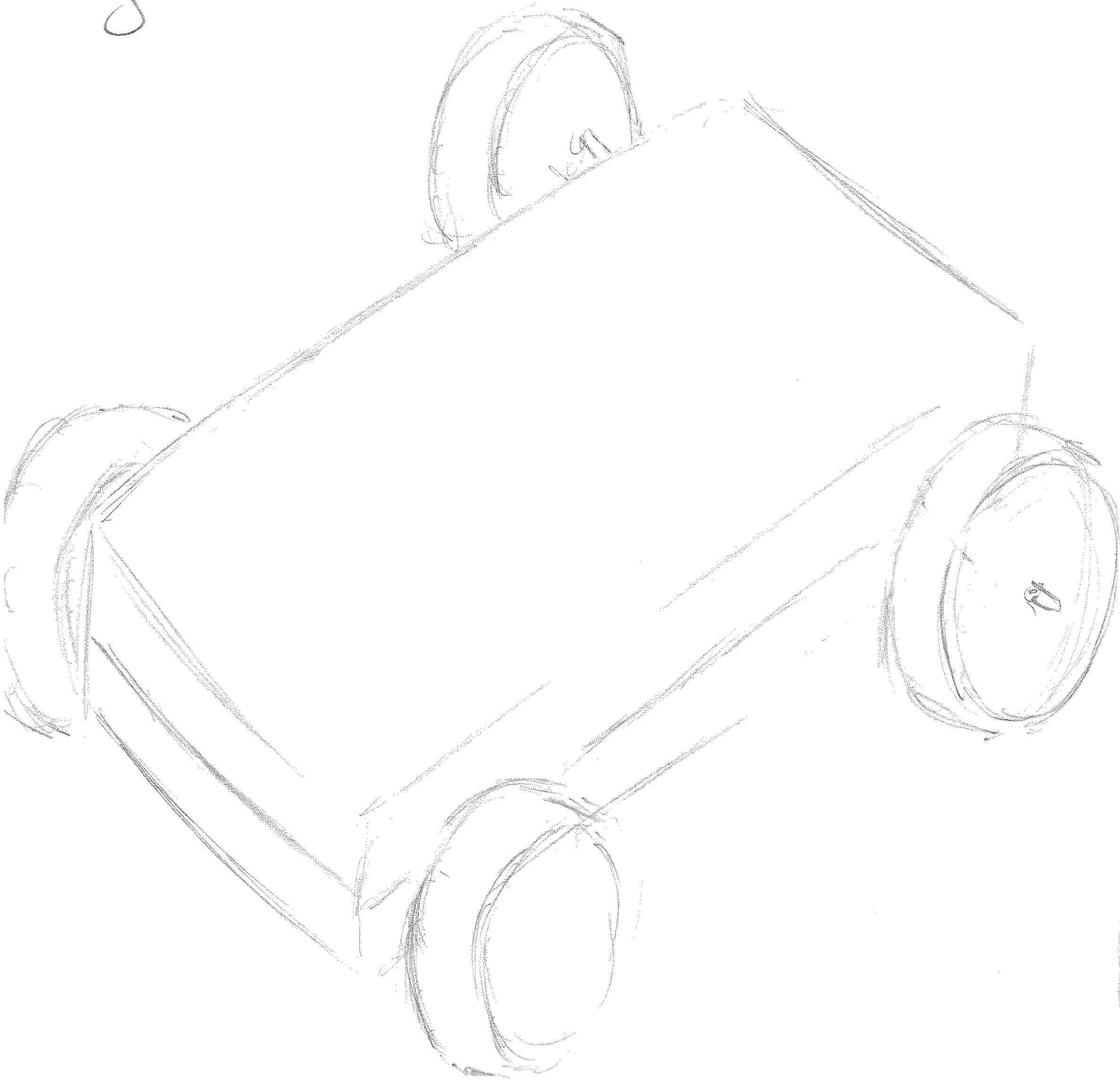
problem with floor? maybe not the winding of thread at that particular distance might have problems

on the track, the car unexpectedly ~~turned left again and devastat~~ingly crashed, leaving the race unfinished. Another unexpected thing with our car happened during the tug-of-war competition. During our battle against the other Anoop team, the output shaft of the gearbox spun independently from the drum it was attached to. Because the shaft connected to the gearbox was moving separately, the wheels of our car were not moving to their full extent; ultimately, we lost the battle because of this unexpected problem that arose.

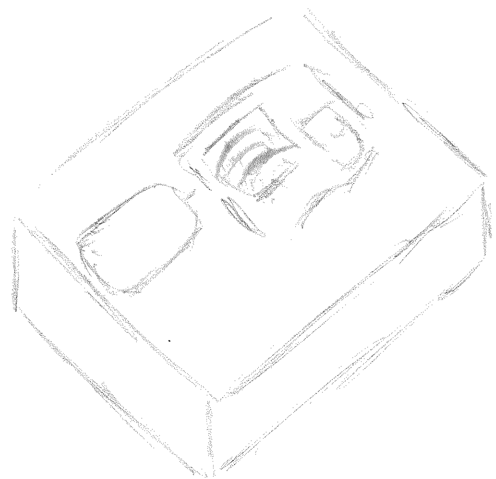
- **What improvements would you make to your design, given its final performance?**
    - Some improvements that we would make to our design, given its final performance is to modify the connection between the gearbox axel and the three wheel piece that wraps the string, fix the car to make it run straight, and adjust our bumpers to work more effectively. To prevent the gearbox axel from moving separately, we would use a different stronger adhesive. During the tug-of-war battle, because of the time constraint we basically used hot glue to stick them together. The hot glue was also not completely dried when we went into the second take of the "Anoop" battle. If we would have used a stronger adhesive like epoxy and let it dry completely, the gearbox axel would have rotated more in sync with the three wheel piece of the string-cone system. To fix the curving problem of the car, we would redistribute the weights on top of the car so that both left and right sides have the same amount of weight on it. The slight unbalanced weight distribution of our car contributed to the problem of our car not going straight. To make the car run even more straight, we could have also extended the distance between the front and rear wheels. Another improvement we would make to our design is to change the position of the bumpers on our car. The bumpers on our car were not very effective and did not prevent our car from failing after crashing into the wall, because they were not placed correctly on the car. Therefore, we would make an adjustment to the bumpers by moving them far more forward, so the bumpers stick out a good amount in front of the car. This adjustment would make the bumper more effective and would give the car a lower possibility of falling over after a crash into the wall.

maybe not (because it was so sudden)

Figures 1

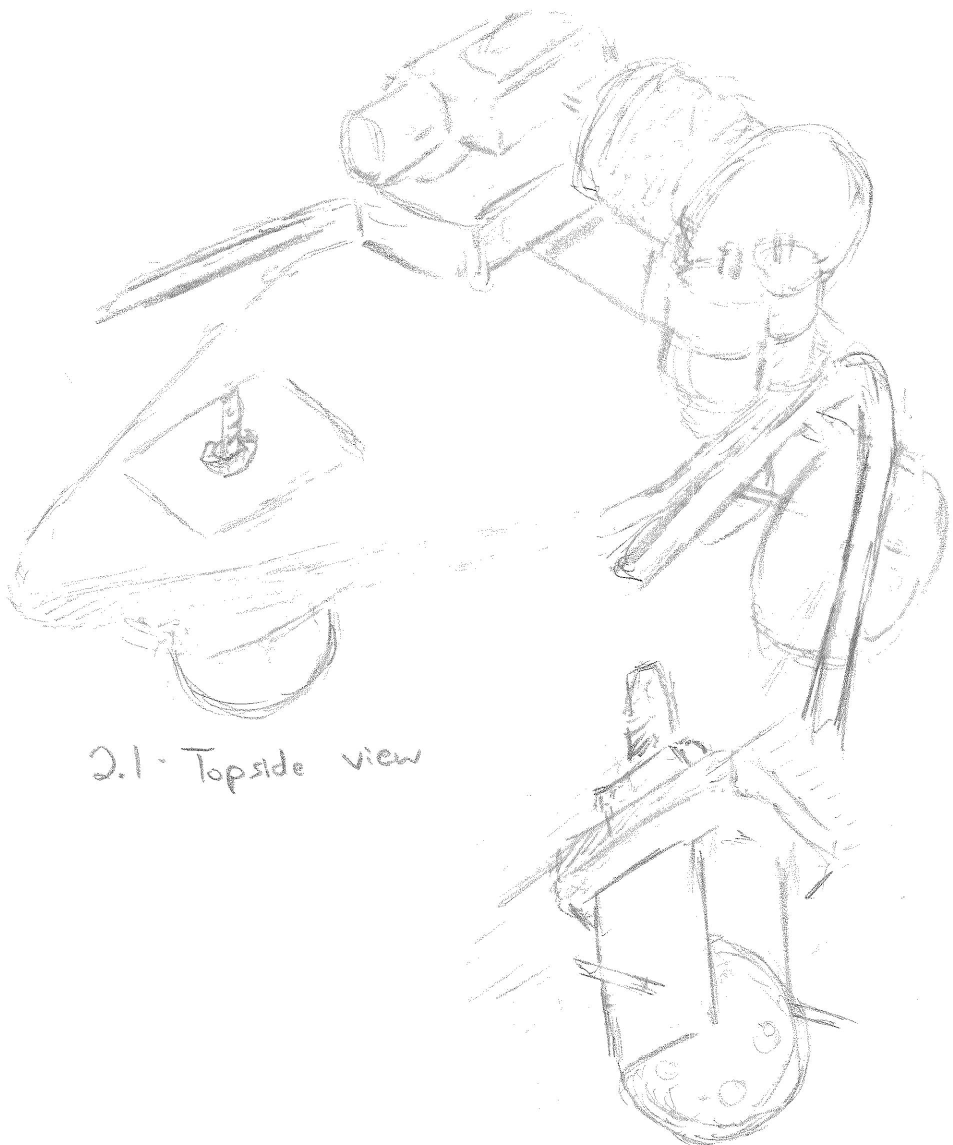


1.1 "The brick?"



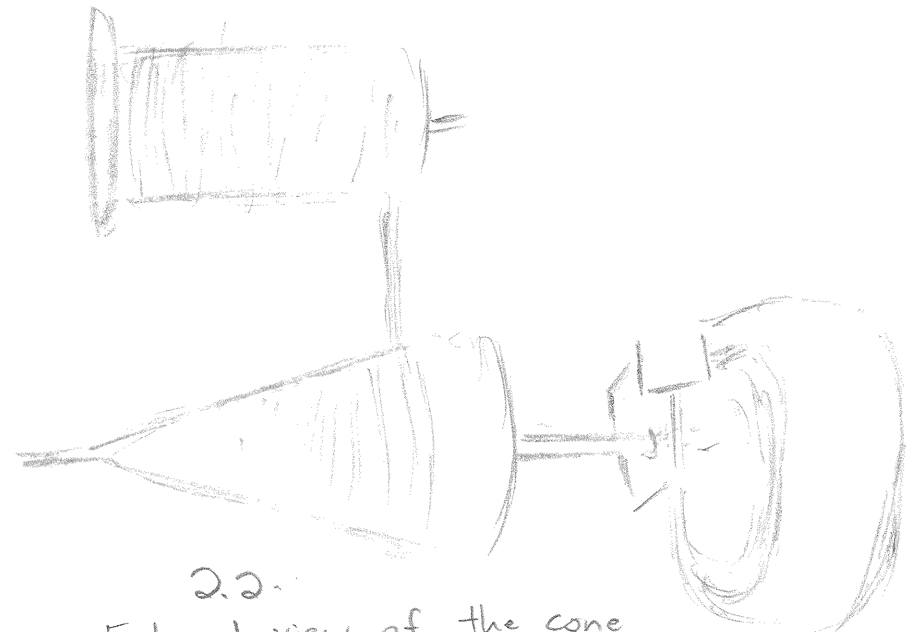
1.2 Motor and gearbox imprinted in Styrofoam

Figures- 2



2.1 · Topside view

2.3 Adjustable steering



2.2.
Enlarged view of the cone on the axle.