Final Report

Team: Red Rain

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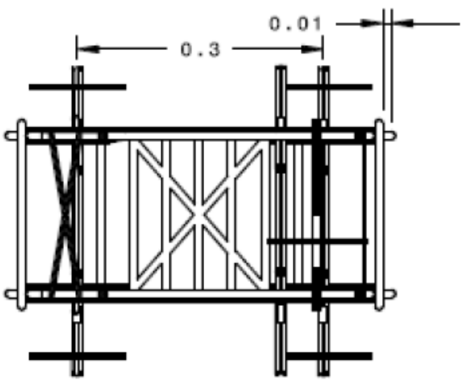
Introduction:

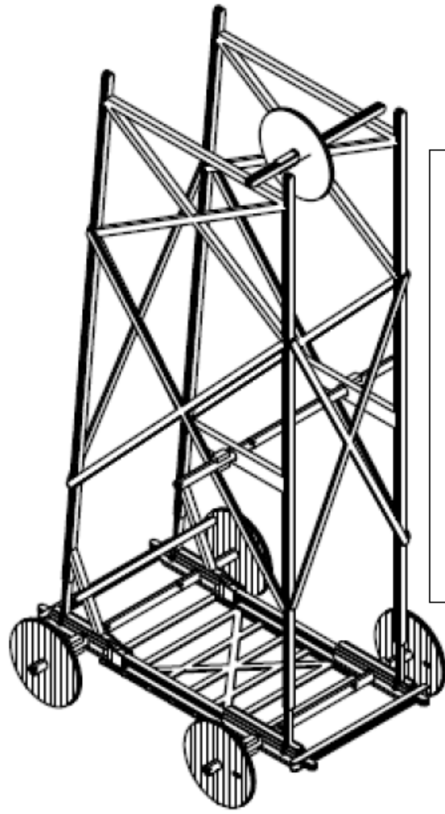
Ever since Henry Ford created the first patented automobile, the world quickly learned of its power and efficiency. In this project, the same fundamentals were followed except that we were given the constraints of using only popsicle sticks, string and CDs in order to come up with an efficient design for a weight powered vehicle. There are many different methods of inventing weight powered vehicle mechanisms that can be built for the purpose of this project. One of the many types of designs include a mousetrap kinetic car, where the kinetic energy of the vehicle is obtained from the energy trapped in the mouse spring. However, in essence, due to the constraints on this project, the efficiency of the vehicle to be constructed had to be predetermined through many individual design ideas as well as through modifications of designs that seemed analogous to the purpose of this project.

For the duration of this project, Team Red Rain was able to develop a fully stable design with two weeks remaining before the project competition due date. However, due to some technicalities, a new and improved design had to be developed within the remainder of this time for the project. In this report, we will be analyzing and comparing previous calculations to existing calculations through graphs and equations.

Final Blueprint/Design:



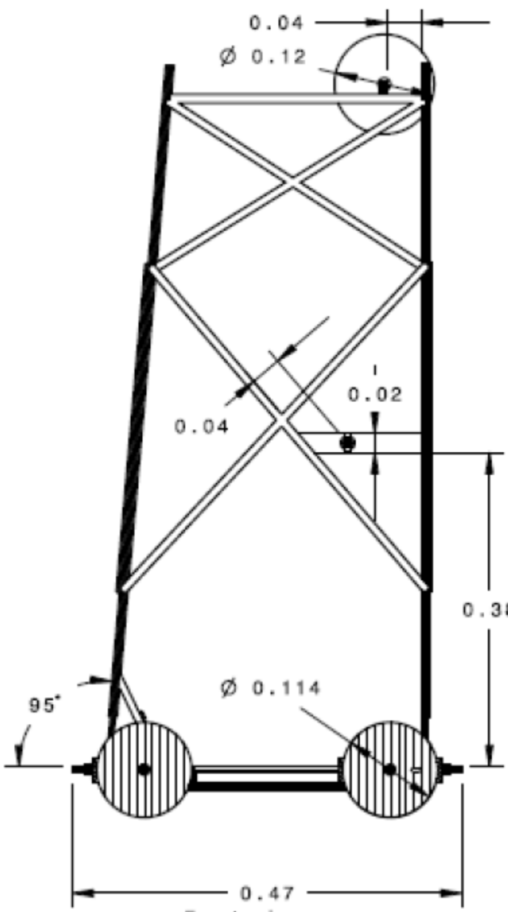
Top view
Scale: 1:8



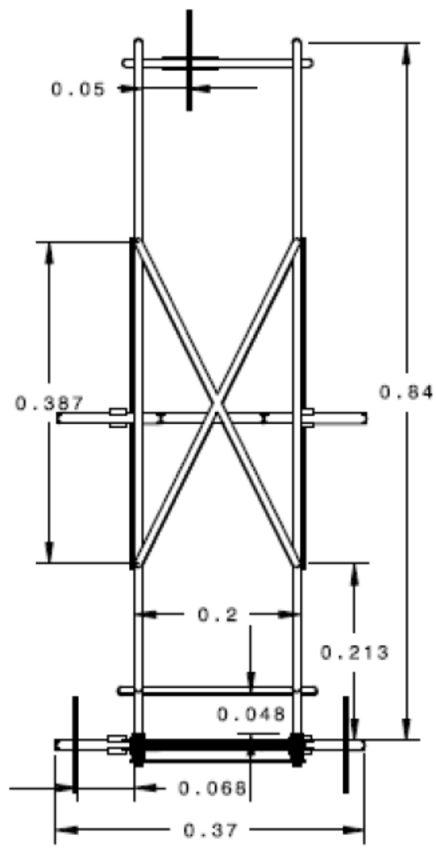
Isometric view
Scale: 1:8

Notes:

Practical design has the support structure 5° away from the vertical in both directions. **Figure 1** only shows the left side having a 5° rotation (front View) from the vertical.



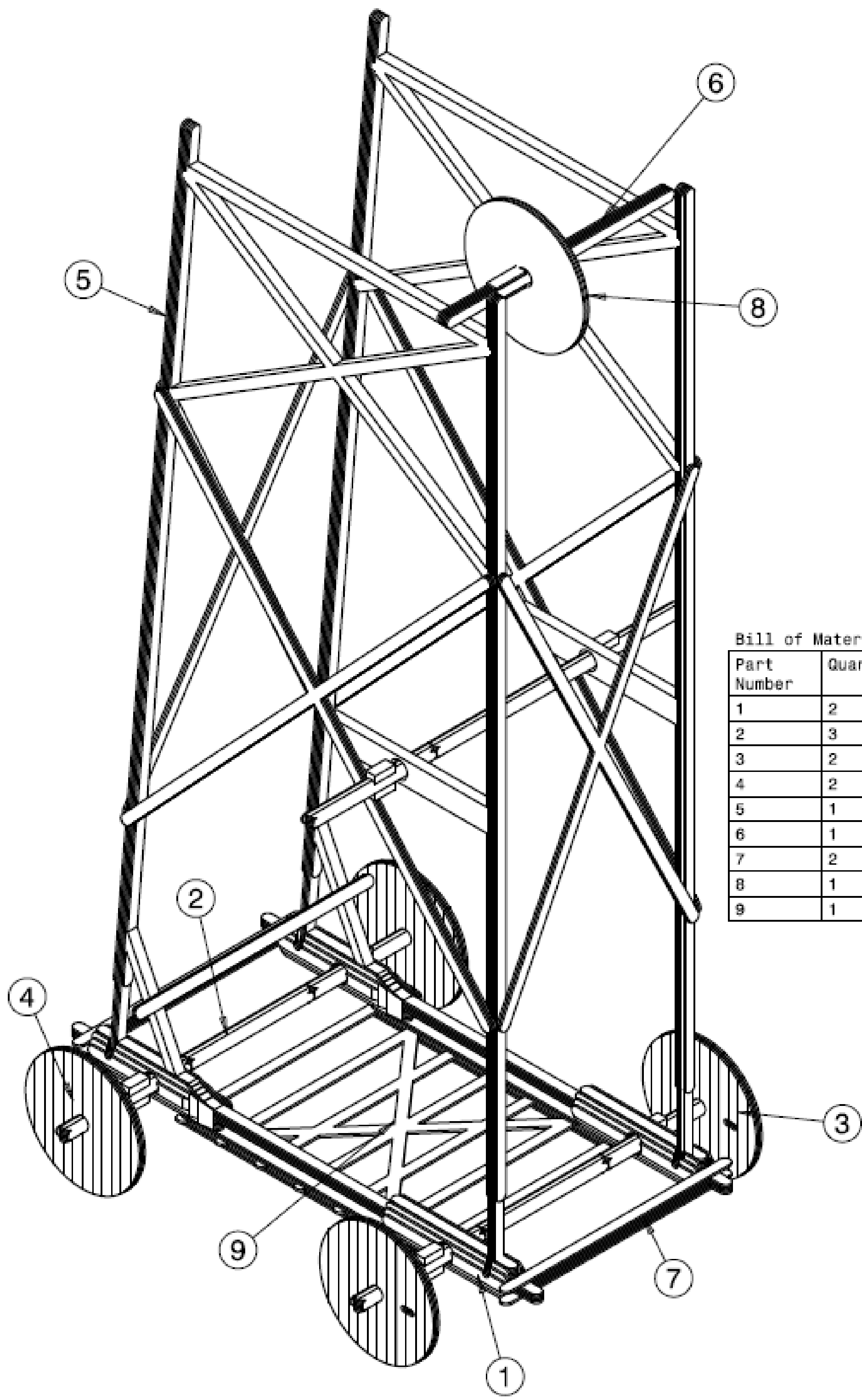
Front view
Scale: 1:8



Right view
Scale: 1:8

Figure 1: Illustrates the relevant dimensions for the final design. Individual part descriptions can be seen in the Appendix.

Bill of materials:



Bill of Material: Product1

Part Number	Quantity	Part Name
1	2	Bottom Hole Support
2	3	Axle
3	2	Brake Wheel
4	2	Front Wheel
5	1	Support Structure
6	1	Pulley Support
7	2	Base Separator
8	1	Pulley
9	1	Basket

Figure 2: Demonstrates the 9 individual components that were used to make the final design. Note: the string here is not shown.

Calculations:

In order to fully understand why the vehicle behaved as it did, one must study its behavior and relative consequences. In this report, our calculations were based off of a video that was taken of our demonstration. A total of 33 time intervals were analyzed for both the vehicle distance (from the front wheel) and the height of the string from the top of the mass. Three graphs (Figures 3, 4 and 5) were computed ($x(t-t')-x(t)/\Delta t$ vs. $x[t]$, U_{loss} vs. $x(t)$ and U_{loss} vs. $x(t-t')-x(t)/\Delta t$) with the aid of Microsoft Excel.

Initially, our calculations (see Appendix) were based on simple kinematic equations and standard physics fundamentals. There were many assumptions made in order to calculate the desired distance that the car would travel. A total of two scenarios were assumed.

The first scenario implicated that the mass would remain standing on the basket and the latter scenario where it would tip over. Ideally, the team wanted the mass to tip over since it would increase the string length and allow the axles to rotate more. This was because the formula used to calculate the amount of spins involved was dividing the length of string from the pulley source (to the mass) by the axle circumference.

Similarly, the calculations used for the final design use the average length of string out of the two scenarios (which equates to roughly 0.834m) obtained from the initial calculations. This is used as the highest possible length that the mass can be attached up to but is not referenced from the ground but rather from the top of the basket, which itself is 1.5cm off the ground.

In all of the graphs below, we are assuming the following things:

- No slip, anywhere
- Tension in string is enough for mass to fall down
- Support structure can hold mass without deforming
- String does not break/snap
- The string is not wrapped on top of itself
- String only moves in the y-direction from the pulley source
- The mass will always tip forward (away from the rear axle)

Note: all data used to generate these graphs can be found in the Appendix.

Figure 3 (next page) exemplifies the relationship between velocity and displacement. At 4.75s, the weight powered vehicle (WPV) reaches a maximum experimental velocity of 1.8 m/s. At this point, the counterweight is 13 cm above the basket while the WPV has already covered a distance of 4.05 m. From then onwards, the car continues to travel through the conversion of the maximum potential energy to kinetic energy. By 5.25s, the counterweight has made an impact with the basket and the WPV progresses with its reducing kinetic energy for another 3s. The trend line clearly indicates the fact that the WPV started from a position of rest to reach a maximum velocity and then goes back to rest.

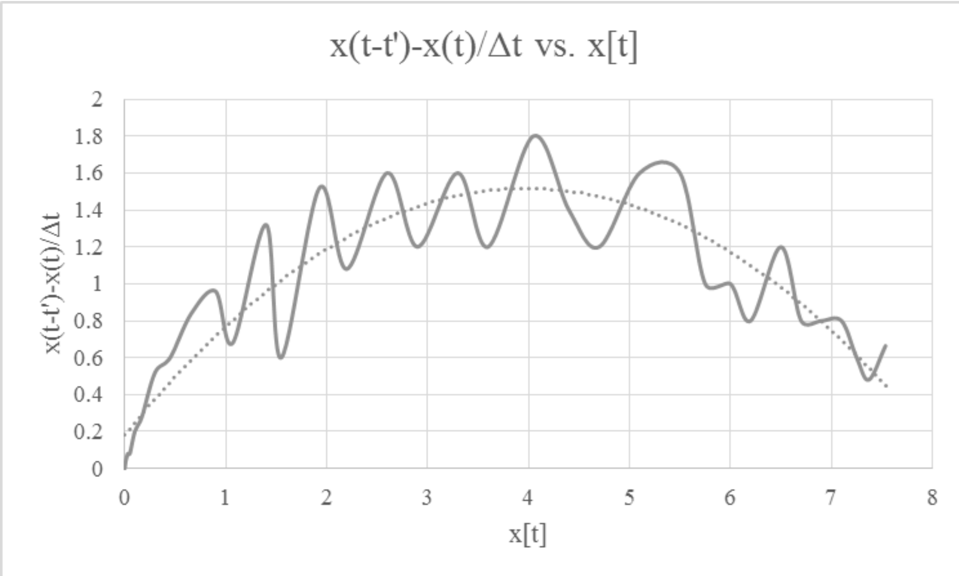


Figure 3

Figure 4 exemplifies the relationship between energy loss (loss of total energy) and displacement. At the maximum velocity in 4.75s, the WPV is losing about 6.7558 J after covering 4.05 m. After covering about 4.5 m, the WPV is losing little to no energy (0.7832). At the end of covering about 5m, the WPV is losing very little energy as most of this energy has already been converted into kinetic energy through conversion from potential energy after the counterweight dropped. The trend line here indicates how from rest, maximum potential energy was converted into kinetic energy and in that process, after taking note of all losses in energy, distance was covered after 8.25s.

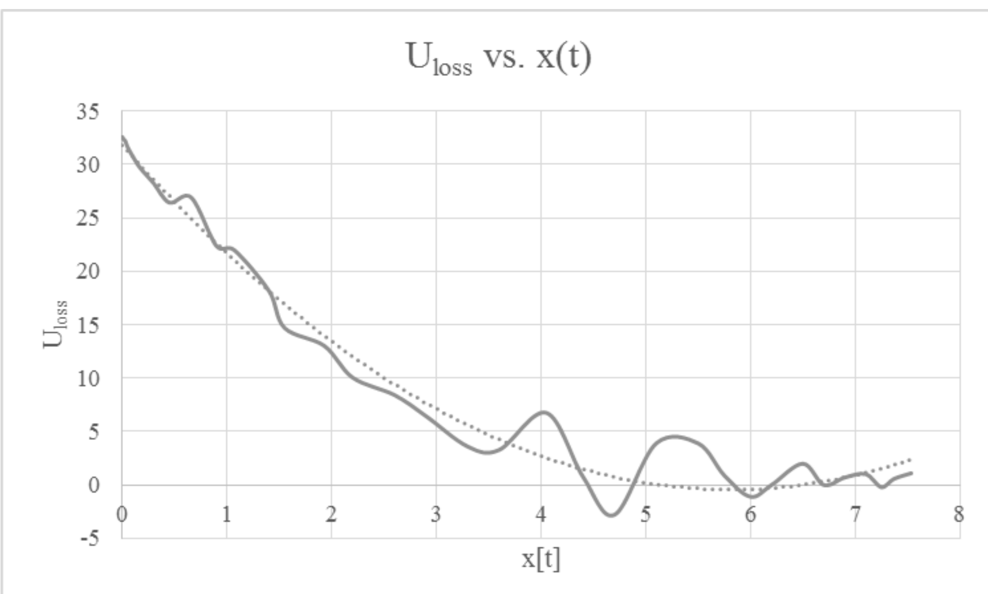


Figure 4

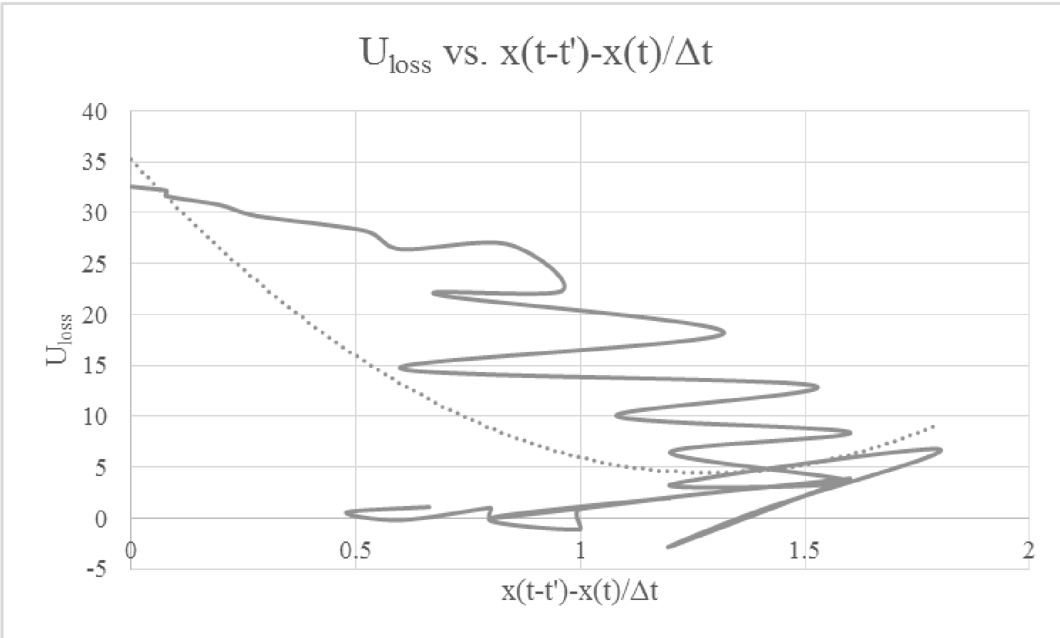


Figure 5

Figure 5 exemplifies the relationship between Energy loss (loss of Total Energy) and velocity. At the maximum velocity of 1.8 m/s in 4.75s, energy loss comes up to about 6.7558 J. At this point, most of the maximum potential energy at the beginning is completely converted into kinetic energy. By 5.25s, when the counterweight has made an impact with the basket, the WPV is only moving due to kinetic energy. However, this kinetic energy reduces over the span of the next 3s bringing the WPV to a complete stop after about 8.25s. The graph clearly implicates the conversion of maximum potential energy to kinetic energy through the decline of the trend line curve, as indicated in the graph.

The final graph (Figure 6) here exemplifies the relationship between change in total energy loss and displacement. This relationship indicates how change in energy keeps declining as distance increases. The trend line also clearly indicates the declining change even with the fluctuating values. The fluctuations were established through some jerks in the weight powered vehicle's motion right before the counterweight made an impact with the basket. By comparison, the experimentally obtained energy loss describes the instantaneous loss in energy at a particular point of motion or instance but the change in energy describes the fluctuations in energy loss over a certain distance covered. Change in loss of energy can be described from the graph to be a value that is declining towards a zero value after reaching a max velocity, indicating how the WPV has a lot of fluctuations in energy loss change when it reaches maximum velocity and therefore, having a negative sloped trend line with a closed parabola. However, instantaneous loss in energy can be described from the experimental data/graph to be a value that is initially declining then reaching a positive equilibrium towards a zero value, indicating the conversion of potential energy to kinetic energy and therefore, having a negative slope trend line with an open parabola. Here, it can be noted that change in energy reaches a max value but instantaneous energy reaches a min value. However, that being the case, both curves of the trend lines have their latter part of the curve going towards equilibrium.

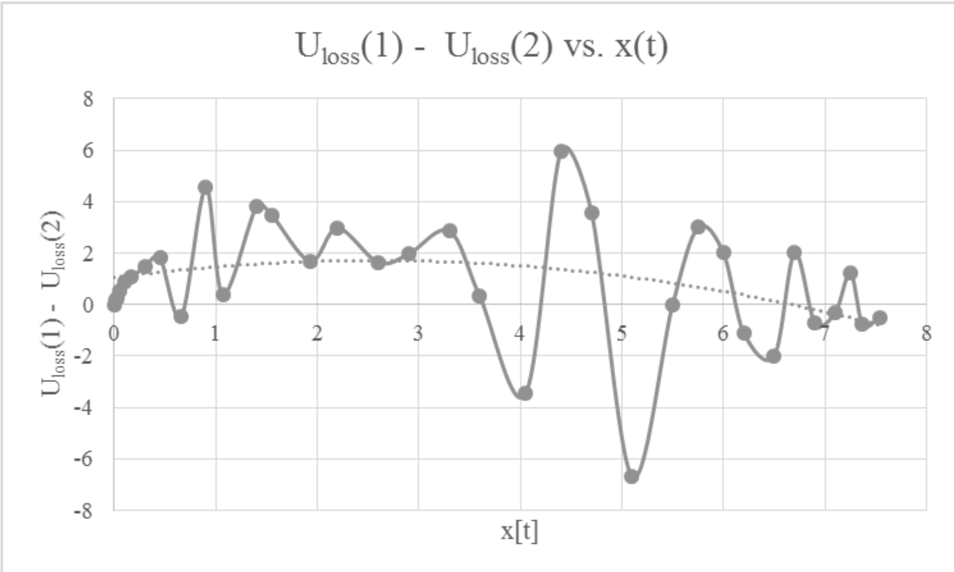


Figure 6

<u>Strength member testing:</u>

In order to test the durability of the weight powered vehicle, a replica of the pulley support was created and placed on the support structure in the exact same location as the one used for the final design. Since this would be the only part of the weight powered vehicle that would experience the most stress, the team believed that this should be the only suitable candidate for strength testing. They were well aware that that the support structure and other parts would hold the 4kg mass without any assistance as this was the second model they had built.

Once completed, a ten pound dumbbell (roughly .5kg more than the desired mass) was attached in a closed loop on the structure (30cm off the ground) and was left suspended until the pulley support snapped. It took a period of four hours for the pulley support to snap in half. The team believed that this was because the alignment of the pulley was directly in the center of the pulley support, which also happened to be in the middle of one of the seams that connected the individual layers of popsicle sticks (see Figure 7). Hence, by learning from this, the team shifted the pulley towards the edge by 3cm and placed it in the center of a fully five layered structure of popsicle sticks (shown as “no seam” on diagram). This was tested for a period of two days and there was no noticeable deformation. The figure below (Figure 7) shows what is meant by the term “seam” used in throughout the report.

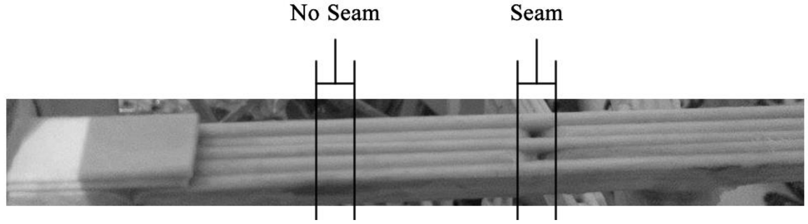


Figure 7

Free body Diagrams:

Problems noted through Final design:

- Adhesive used was wood glue which took a relative time of about 15 minutes to enforce its support onto any and all popsicle structures. Since there were several components, loss of time became a huge factor in determining the efficiency and success rate of the project.
- Positioning of the holes and relative drill jobs had to be very precise. Therefore, any mistake(s) had to be compromised for in the design through symmetrical assigning of components for the WPV (Weight Powered Vehicle).
- The clamping procedure, which used binder clips, usually disoriented the popsicle stick layers. Hence, popsicles with straighter grains and stability were selected.
- Deciding between what kind of adhesive to use to increase maximum efficiency and hold the bonds between certain materials without altering components (i.e. CDs and popsicle sticks) was quite costly. The team had to be careful and use protective gear when using certain materials as they were permanent and did not have a solution.
- Since the glue, gorilla glue, used was somewhat permanent, it was very inconvenient for the team to change or adjust components as often since other parts would end up breaking in the process.
- Earlier designs and research revealed that different types of pulleys were constructed for a weight powered vehicle. Since the project implies the idea of reducing total mass as much as possible, developing a brand new design for a pulley that did not weigh too much and was also able to hold the counterweight, was a tough task in itself.
- The "sailor knot" that was created for the purpose of holding the counterweight, was explicitly meant for holding the counterweight assigned. However, during trial tests, similar counterweights weren't available. Therefore, the "sailor knot" was used extensively in holding a 10lb (4.5kg) dumbbell causing the knot to go through wear and tear.

Conclusion:

Although Red Rain did not achieve the desired turnout of 25m, it did have the best performance to weight ratio out of all the contestants. The new vehicle traveled a distance of 7.936m and had a weight less than 1kg (996g to be precise); equating the ratio to be 7.967.

Previously the design was made from a combination of hot glue and CDs. However, it was not very efficient as the team noticed several deformations starting to occur when the structure was stress tested with a 10lb (4.5kg) dumbbell for a total of 4 hours. The new vehicle was constructed using Gorilla glue and PVC wood glue. The team found the adhesive yielded a much stronger bond between the popsicle sticks and lasted much longer.

If the group performance was based on the average of all three tries, the group would have done poorly as compared to the latter scenario. The weight powered vehicle failed to launch on the first two tries because the tension in the string was slightly high. The vehicle only needed a slight drop in weight for all the mechanisms to start working properly. Hence on the final try, the group decided to rotate the wheel a little and then apply the brake and quickly remove it. Although this made the car function properly, the car could have went further if the mass was suspended higher and not at the bottom of the "sailor knot" as it was made too loose; not to mention that it was already worn out from previous tests.

If more tests were done to see how many loops of string had to be around the axle for the mass to fall down smoothly, the first two tries would not have failed. Also if the "sailor knot" was tied smaller, the placement of the mass would have been a lot higher and the car would have resulted in a longer distance traveled. In the end, this design challenge showed that it is always best to know the limits in which one can bend the rules with and be ready for any scenario appropriately. We did not know that we could use a "door stop" mechanism as our breaks until the very last minute.

References:

"Cutting out the axles.." *Instructables.com*. N.p., n.d. Web. 22 June 2014. <http://www.instructables.com/id/Popsicle-Stick-Racecar/step6/Cutting-out-the-axles/>.

"How to Build a Popsicle Stick Tower." *wikiHow*. N.p., n.d. Web. 21 June 2014. <http://www.wikihow.com/Build-a-Popsicle-Stick-Tower>.

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Construction Procedure:

After having modified the final design at least two times, Red Rain was able to come up with a functional design that both met the requirements and was suitable for trial. A lot of facts and assumptions that were made in the previous designs aided in the theory behind the final design. Although most of our findings were predicted by trial and error, some of the calculations did resemble our best trial, which was 7.936m (see Appendix-Initial Calculations). Unlike the previous design, where difficulties lied in coming up with making the axle in particular, it was solved by having a layer of popsicle sticks (6 on top of each other and one on each side (see Figure 1)) and having them rounded off through a wood shop. A total of three axles and four wheels were constructed there.

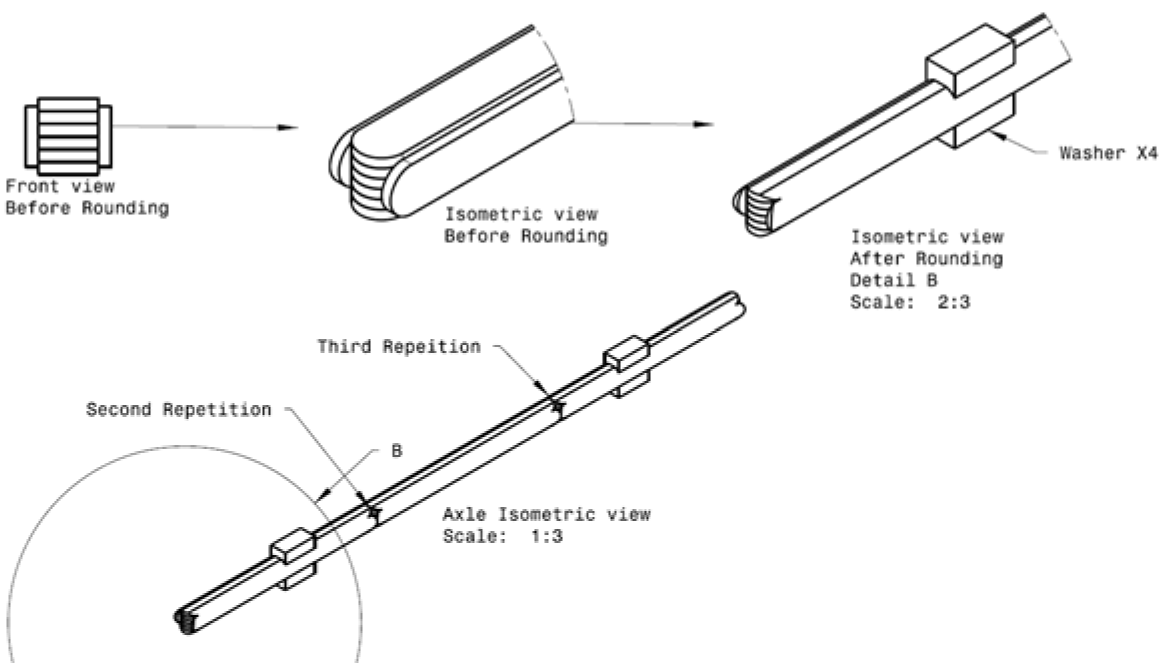

Figure 1: Illustrates the construction process of the three axles that were used in the final design. The inner six popsicle sticks were arranged in a brick layout with an offset of a half popsicle stick per layer. The four washers were added after the support structure and two bottom-hole supports were made. This was to allow them to go through the desired holes and prevent the axle from sliding out of the vehicle. The washers were fabricated from two layers of popsicle sticks that were cut (2 x .96 cm) and glued on top of each other. They were placed 3cm away from the second and third repetitions.

Both the front and brake wheels were constructed with three layers of popsicle sticks that were arranged in a vertical-horizontal-vertical arrangement. This not only made the bond between the popsicle sticks stronger but allowed the wood shop to easily round off the square shape into a wheel which was 11.4 cm in diameter. The figure below shows both the front and brake wheels. The brake wheels have a slot 3cm away from the center of the wheel to allow a stack (approximately two layers) of popsicle sticks slide through the wheels and act as a braking mechanism. This was before the team realized that a door stop mechanism could be used as the brakes.

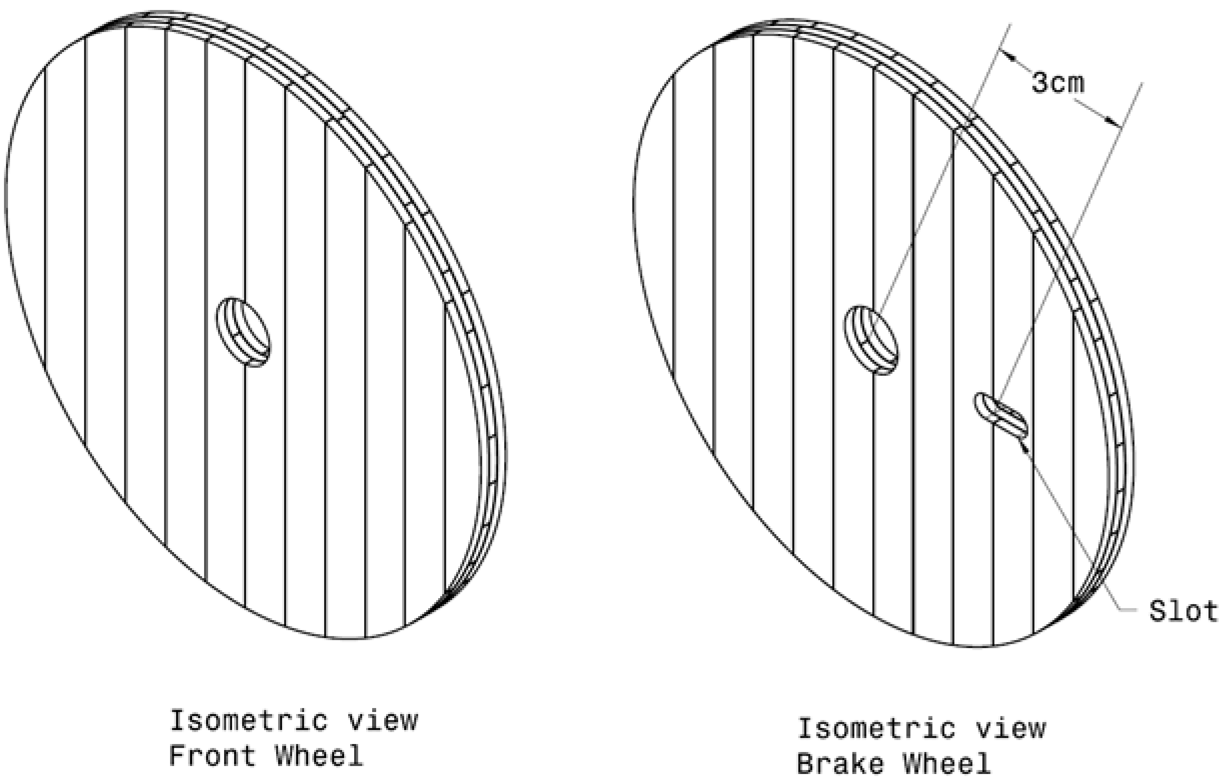

Figure 2: Illustration of both the front and brake wheels. They have the same diameter (11.4cm) and hole (1.27cm). The slot on the brake wheel is 3 cm away from the center of the brake wheel center hole. It is two popsicle sticks thick (.4 x .96).

The pulley support was constructed by stacking up to five layers of popsicle sticks on top of each other at a perpendicular format to the top of the support structure. Now, in order for the pulley to stay intact i.e. exactly where the group wants the pulley's position to be on the pulley support, the group decided to create a pair of washers similar to the two layer popsicle stick fabrication mentioned earlier. The washers are separated by a 0.46cm gap to allow enough space for the pulley the pulley to rotate freely. The pulley itself is a structure made by stacking a cd on either side of a popsicle structure meant for the string to rotate around. These dimensions will be later mentioned in the pulley structure.

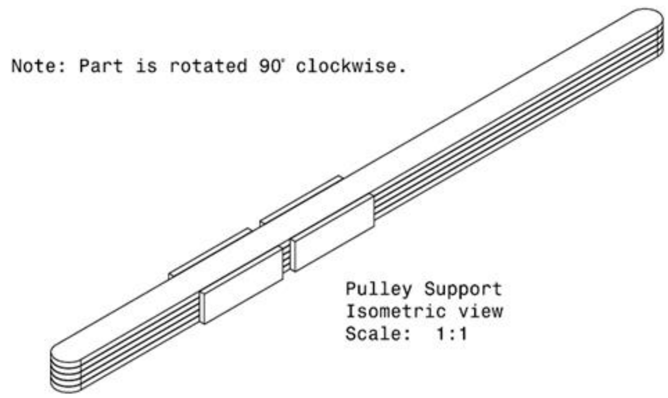

Figure 3: Demonstration of the pulley support and washers being positioned 6cm and 9.5cm from each end. This was attached to the top of the support structure and placed 5cm away from the top right most edge.

The bottom hole support, by the name itself, exemplifies the definition of supporting the axles for the wheels of the WPV. However, this was not only its sole purpose. The bottom hole support was also responsible in maintaining its posture and holding the support structure. Detail A in the bottom hole support structure signifies the distinction of the front and back wheel locations of the WPV. Also, this detail was implemented in order to reduce the overly exerted weight due to heavy stacking of popsicle sticks and create a slot for the counterweight basket to rest on top of the bottom hole support. It could definitely be called the base support. Detail B exemplifies the location of the slot for the support structure to rest on. The slot's depth is exact enough so that the support structure's height does not exceed 95cm. Along with this detail, in order to make the structure stronger, a pyramid arrangement of popsicle sticks was constructed. This increased overall strength and support of the base.

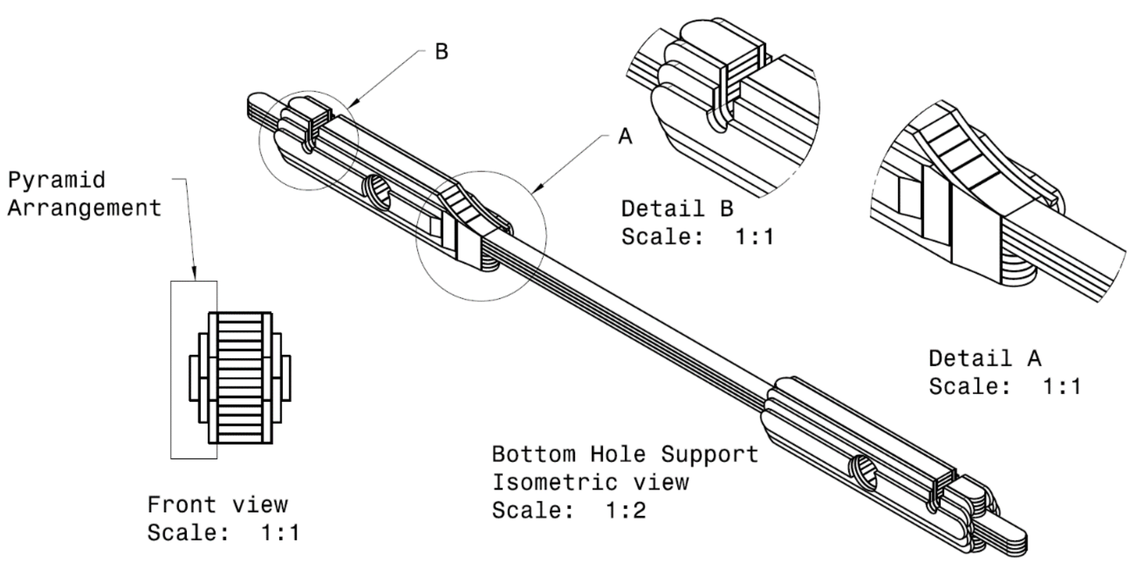

Figure 4: Illustrates the detail and reinforcement that was put into the base support as shown in details A and B.

The two bottom hole supports were connected with the base separator, which was roughly 18cm in width (from one cutout to the next and the whole base was 20 cm apart (see Final Design Draft)). This was one of the simplest and unique parts to model as it did not follow the alternating arrangement of popsicle sticks per layer. This was not offset by half of a popsicle stick; it was 6cm. The top and bottom layers were glued to the middle layer of popsicle sticks and was 24cm in length.

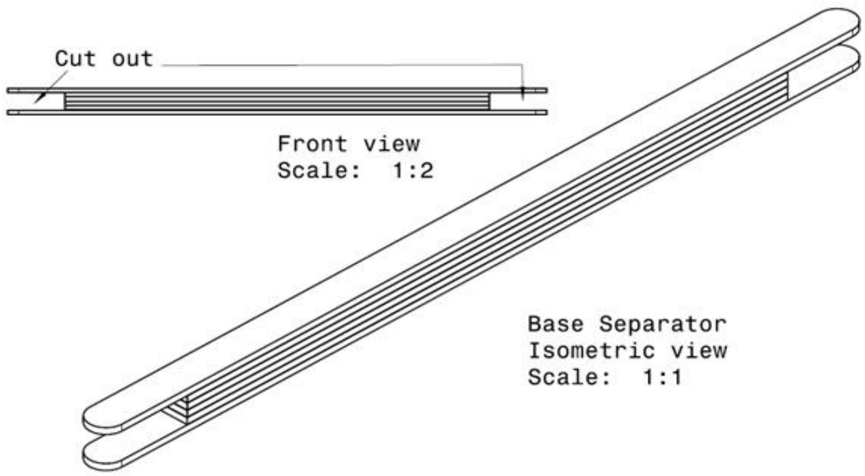

Figure 5: Illustrates the base separator. The two cut outs shown represent the area where the bottom hole supports would attach.

Making the basket was not much of challenge either, unlike the previous design, where the mass was supposed to remain standing, the team found a better solution. Instead of keeping the mass standing they decided to go ahead and make the basket in a way so that the mass tips over. This made it so the string would travel a longer vertical distance (.9035m to be exact) rather than 0.774m as calculated (see calculations). It was made by making two layers of popsicle sticks that were 24cm long four times (two for each side). The structure in the middle was fabricated and sandwiched between these four popsicle stick members as shown.

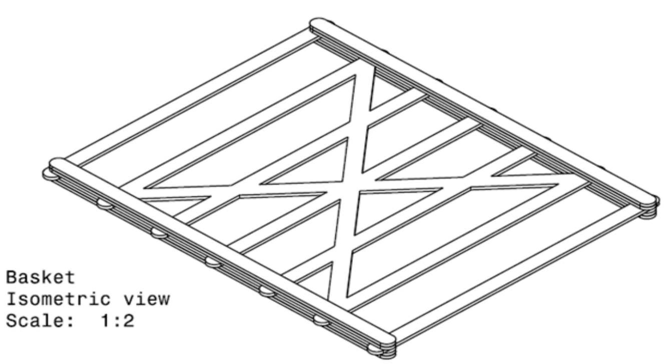

Figure 6: A visual representation of the basket that was attached underneath the two bottom hole supports.

Making the pulleys was one of the easiest things the team had to do as this required no alteration or cutting of popsicle sticks like the front and brake wheels. They were made by stacking up two CDs (compact disks) together with a square structure in between that was roughly 4cm x 4 cm.

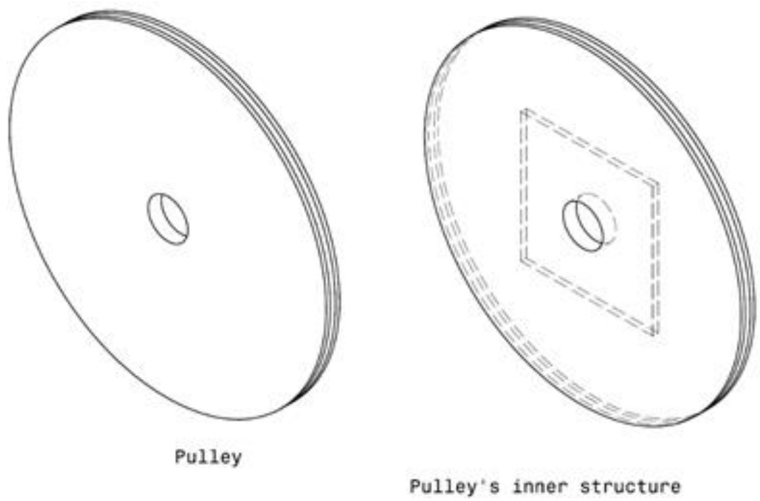

Figure 7: Illustrates the pulley on the left and the pulley’s inner structure on the right. The team decided to go with a square inner pulley separation because it feared that the string would slip if it was circular.

One of the most complex parts to be built, the structure was 85 cm high and was angled 5 degrees from the vertical (on both sides). The pulley support is held by this support structure which is an accumulation of several popsicle structures. Detail A exemplifies the location of the second axle where the string from the pulley is further rotated around in order to increase the frequency of rotations of the string around the pulley in order to gain overall max conversion of potential energy from counterweight to kinetic energy for distance. Detail B exemplifies the location of the counterweight holder that the group decided to install into the support structure. This occurred due to the realization that the counterweight basket that was designed to hold the weight when it fell during performance, intentionally made the counterweight tilt towards the direction of the counterweight holder upon impact on basket. Detail C, as shown the Figure, exemplifies the location of the pulley support and, was obviously, the most important part to the support structure. The joint was strengthened enough at that angle in order for the pulley support to perform efficiently.

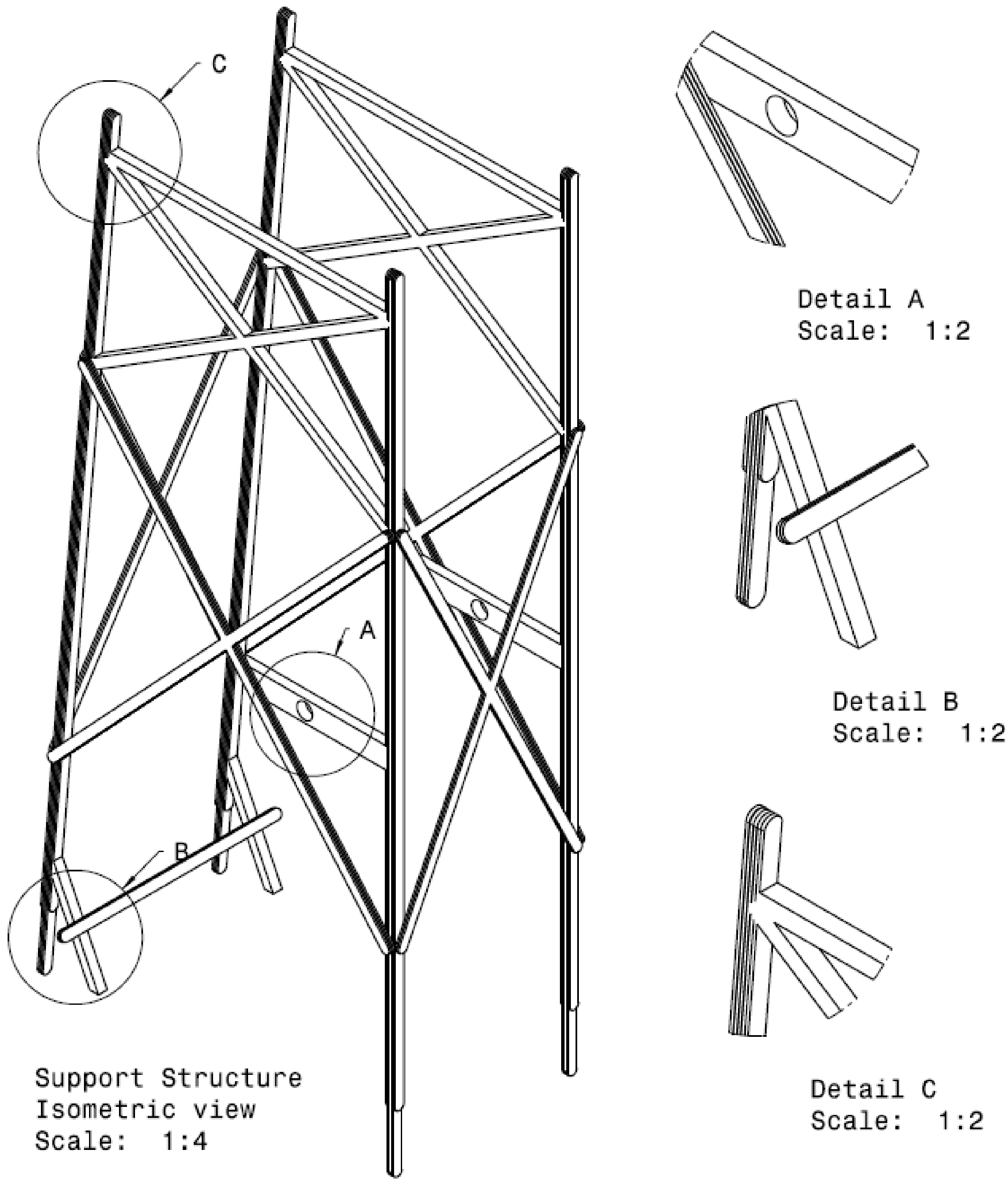

Figure 8: Shows the support structure and three details A, B and C which were crucial to the design.

<u>Problems noted throughout project:</u>

Milestone#1:

- Determining methods around the given constraints for this assignment
- Determining the layers of popsicle sticks to be used in order to support each component
- Determining an axle design that was easy to construct and efficient
- The fact how CDs cannot be altered has become a problematic constraint hence calibration of popsicle stick layers for the axle as well as the support keeps changing in order to avoid damage and/or alteration to the CD structure
- Even though support of the mechanism is guaranteed, hot glue takes up a lot of space in most components where space to apply support becomes insufficient
- The angle at which the pulley supports should be placed in order to let the counterweight fall through the entire height without collisions

Milestone#2:

- Due to huge constraint on materials as previously mentioned, construction and reconstruction of physical model ultimately makes the model very tough to remodel
- The hot glue, being a very effective adhesive, executes its proper role of keeping the components together, making it difficult to edit or make any changes to the design in general
- Also, due to how most of the construction of the model is done in a very permanent manner (constraints), the overall performance of the physical model decreases as details like friction, which should be minor in this case becomes a major detail
- Another issue the team encountered was during the initial phases where the physical model didn't move straight and the support was wearing off after a few tries/performances. The issue was met with proper alignment and modular setup. However, this had to be done every time issues were encountered
- The support for the pulley mechanism, which will be the bulk of the design of Team Red Rain's Weight Powered Vehicle (WPV), is very difficult to construct. This is because the constraint on the physical model can make the overall weight to become all that it takes for the entire model to deteriorate.
- Determining the appropriate strength for the pulley mechanism to hold itself along with the base constructed with it. It must be strong enough to withstand a 4kg mass.

Initial calculations:

Assumptions:

The following assumptions were made in order to calculate the following distances in the respected scenarios:

- No slip, anywhere
- Tension in string is enough for mass to fall down
- Support structure can hold mass without deforming
- String does not break
- The string is not wrapped on top of itself
- String only moves in the y direction from the pulley source

Assuming the mass does not tip over:

D=diameter C=circumference H=height

R=radius

Circumference of a circle = πD or $2\pi r$

D_{axle} = 0.5 in = 0.0127m $C_{\text{axle}} = \pi(0.0127) = 0.0398$ m $C_{\text{wheel}} = \pi(0.114) = 0.358$ m

H_{car} = .95m H_{mass} = 6.33in = .161m H_{basket} = .015m

$L_{\text{string}} = H_{\text{car}} - H_{\text{mass}} - H_{\text{basket}}$ = .95 - .161 – 0.015 = 0.774 m

Amount of axle spins = $L_{\text{string}} / C_{\text{axle}}$ = 19.4 spins

Since the wheels are directly glued to the axle, they will have 19.4 spins as well

Distance Traveled = Amount of axle spins * C_{wheel} = **6.95m**

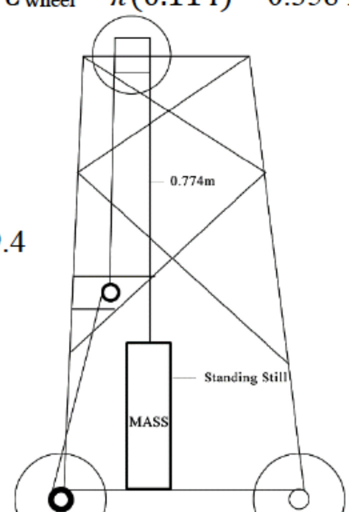

Figure 9: Shows the mass in a perfectly standing position under the pulley. The string has a length of 0.774m.

If mass tips over and lands in the ideal position:

R_{mass} = 0.0635m/2 in = 0.03175m

$L_{\text{string}} = H_{\text{car}} - R_{\text{mass}} - H_{\text{basket}}$ = .95 - .03175 – 0.015 = 0.90325 m

Amount of axle spins = $L_{\text{string}} / C_{\text{axle}}$ = 22.7 spins

Since the wheels are directly glued to the axle, they will have 22.7 spins as well

Distance Traveled = Amount of axle spins * C_{wheel} = **8.1266 m**

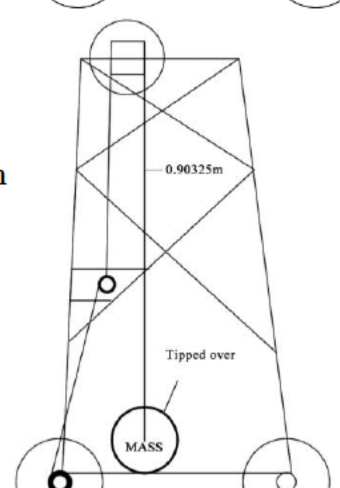

Figure 10: Shows the mass tipped over perfectly under the pulley allowing the length of the string to increase by roughly 13 cm from scenario 1 (Figure 8).

Obtaining data from a video:

After obtaining a video clip of our weight powered vehicle it had to be edited so only the relevant information was analyzed. The clip was originally 15.52 seconds long and was trimmed down to 8.26 seconds with 255 frames in total. The picture below shows how the team studied the desired distances x_n[m] (0.45m) and y_n[m] (0.822m) from the picture at every 0.25s interval.

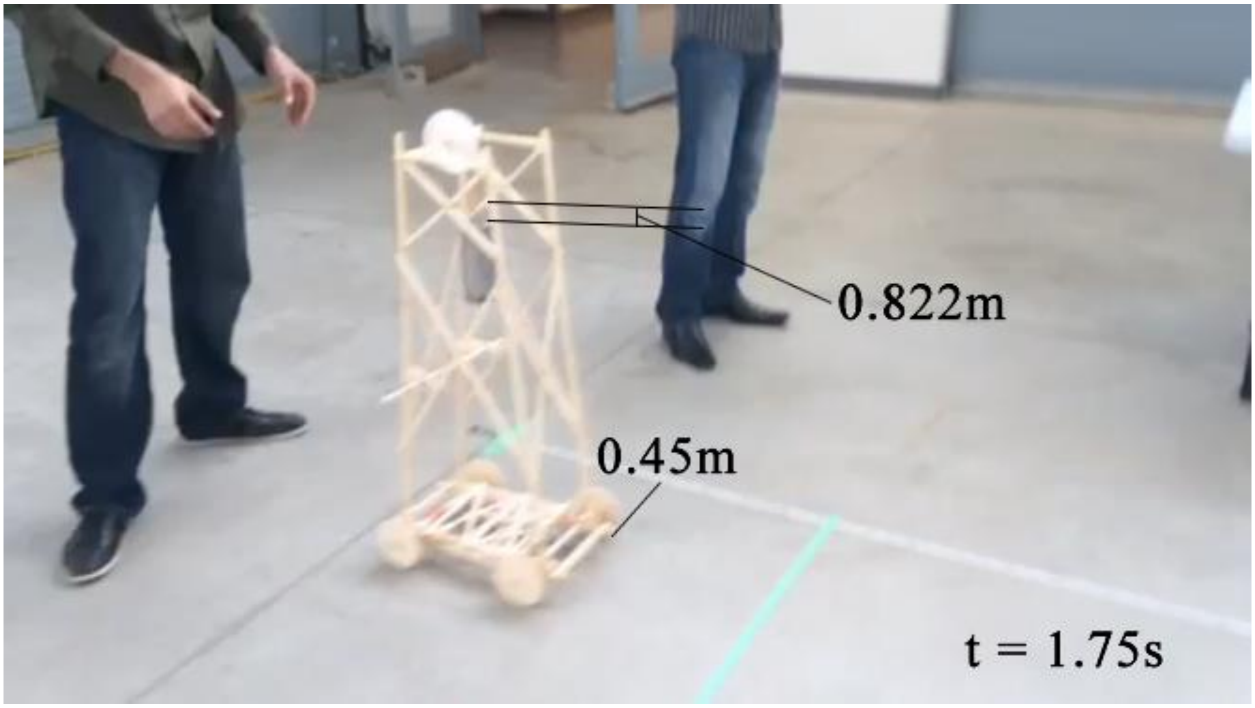

Figure 11: Demonstrates how the team calculated both the distance of the car and the hanging mass from the top of the pulley. This particular frame is 54th in sequence of 255.

Calculation Data:

Δt	0.25 seconds
M_{mass}	4 kg
$M_{vehicle}$	0.996 kg

				Position 1 VELOCITY (Vehicle)	Position 1 Kinetic Energy VEHICLE + MASS
n	$t[s]$	$X_n[m]$	$Y_n[m]$	$\frac{(X_{n+1} - X_n)}{\Delta t}$	$\frac{1}{2}(M_{mass} + M_{vehicle})\left(\frac{(X_{n+1} - X_n)}{\Delta t}\right)^2$
0	0	0	0.834	0.0000	0.0000
1	0.25	0.01	0.83	0.0400	0.0040
2	0.5	0.03	0.827	0.0800	0.0160
3	0.75	0.05	0.822	0.0800	0.0160
4	1	0.1	0.817	0.2000	0.0999
5	1.25	0.17	0.8	0.2800	0.1958
6	1.5	0.3	0.78	0.5200	0.6755
7	1.75	0.45	0.75	0.6000	0.8993
8	2	0.66	0.715	0.8400	1.7626
9	2.25	0.9	0.67	0.9600	2.3022
10	2.5	1.07	0.625	0.6800	1.1551
11	2.75	1.4	0.575	1.3200	4.3525
12	3	1.55	0.49	0.6000	0.8993
13	3.25	1.93	0.42	1.5200	5.7714
14	3.5	2.2	0.36	1.0800	2.9137
15	3.75	2.6	0.28	1.6000	6.3949
16	4	2.9	0.19	1.2000	3.5971
17	4.25	3.3	0.14	1.6000	6.3949
18	4.5	3.6	0.135	1.2000	3.5971
19	4.75	4.05	0.13	1.8000	8.0935
20	5	4.4	0.1	1.4000	4.8961
21	5.25	4.7	0	1.2000	3.5971
22	5.5	5.1	0	1.6000	6.3949
23	5.75	5.5	0	1.6000	6.3949
24	6	5.75	0	1.0000	2.4980
25	6.25	6	0	1.0000	2.4980
26	6.5	6.2	0	0.8000	1.5987
27	6.75	6.5	0	1.2000	3.5971
28	7	6.7	0	0.8000	1.5987
29	7.25	6.9	0	0.8000	1.5987
30	7.5	7.1	0	0.8000	1.5987
31	7.75	7.25	0	0.6000	0.8993
32	8	7.37	0	0.4800	0.5755
33	8.25	7.536	0	0.6640	1.1014
Total					87.9878
				[J]	

Note: Yn[m] starts from 0.834 as that is the average of our two predicted length of strings (see initial calculations). (0.774+0.90325)/2 = 0.834m

		Work of gravity, U	Position 1 Kinetic Energy MASS	Position 2 VELOCITY (Vehicle)
$Y_n - Y_{n+1}$	$Y_n - Y_{n+2}$	$M_{mass}(g)\left(\frac{Y_n - Y_{n+2}}{2}\right)$	$\frac{1}{2}(M_{mass})\left(\frac{(Y_n - Y_{n+1})}{\Delta t}\right)^2$	$\frac{(X_{n+2} - X_{n+1})}{\Delta t}$
0.0040	1.6610	32.5888	0.0005	0.0800
0.0030	1.6520	32.4122	0.0003	0.0800
0.0050	1.6440	32.2553	0.0008	0.2000
0.0050	1.6220	31.8236	0.0008	0.2800
0.0170	1.5970	31.3331	0.0092	0.5200
0.0200	1.5500	30.4110	0.0128	0.6000
0.0300	1.4950	29.3319	0.0288	0.8400
0.0350	1.4200	27.8604	0.0392	0.9600
0.0450	1.3400	26.2908	0.0648	0.6800
0.0450	1.2450	24.4269	0.0648	1.3200
0.0500	1.1150	21.8763	0.0800	0.6000
0.0850	0.9950	19.5219	0.2312	1.5200
0.0700	0.8500	16.6770	0.1568	1.0800
0.0600	0.7000	13.7340	0.1152	1.6000
0.0800	0.5500	10.7910	0.2048	1.2000
0.0900	0.4200	8.2404	0.2592	1.6000
0.0500	0.3250	6.3765	0.0800	1.2000
0.0050	0.2700	5.2974	0.0008	1.8000
0.0050	0.2350	4.6107	0.0008	1.4000
0.0300	0.1300	2.5506	0.0288	1.2000
0.1000	0.1000	1.9620	0.3200	1.6000
0.0000	0.0000	0.0000	0.0000	1.6000
0.0000	0.0000	0.0000	0.0000	1.0000
0.0000	0.0000	0.0000	0.0000	1.0000
0.0000	0.0000	0.0000	0.0000	0.8000
0.0000	0.0000	0.0000	0.0000	1.2000
0.0000	0.0000	0.0000	0.0000	0.8000
0.0000	0.0000	0.0000	0.0000	0.8000
0.0000	0.0000	0.0000	0.0000	0.8000
0.0000	0.0000	0.0000	0.0000	0.6000
0.0000	0.0000	0.0000	0.0000	0.4800
0.0000	0.0000	0.0000	0.0000	0.6640
0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000
		410.3719 [J]	1.6996 [J]	

Position 2 Kinetic Energy VEHICLE+MASS	Position 2 Kinetic Energy MASS	
$\frac{1}{2}(M_{mass}+M_{vehicle})\left(\frac{(X_{n+2}-X_{n-1})}{\Delta t}\right)^2$	$\frac{1}{2}(M_{mass})\left(\frac{(Y_{n+1}-Y_{n+2})}{\Delta t}\right)^2$	ΔU_{loss}
0.0160	0.0003	32.5731
0.0160	0.0008	32.3997
0.0999	0.0008	32.1713
0.1958	0.0092	31.6353
0.6755	0.0128	30.7540
0.8993	0.0288	29.6916
1.7626	0.0392	28.2344
2.3022	0.0648	26.4319
1.1551	0.0648	26.8983
4.3525	0.0800	22.3613
0.8993	0.2312	21.9809
5.7714	0.1568	18.1774
2.9137	0.1152	14.7042
6.3949	0.2048	13.0209
3.5971	0.2592	10.0531
6.3949	0.0800	8.4196
3.5971	0.0008	6.4557
8.0935	0.0008	3.5988
4.8961	0.0288	3.2837
3.5971	0.3200	6.7558
6.3949	0.0000	0.7832
6.3949	0.0000	-2.7978
2.4980	0.0000	3.8969
2.4980	0.0000	3.8969
1.5987	0.0000	0.8993
3.5971	0.0000	-1.0991
1.5987	0.0000	0.0000
1.5987	0.0000	1.9984
1.5987	0.0000	0.0000
0.8993	0.0000	0.6994
0.5755	0.0000	1.0232
1.1014	0.0000	-0.2021
0.0000	0.0000	0.5755
0.0000	0.0000	1.1014
87.9838	**1.6991**	**410.3764**
[J]	**[J]**	**[J]**

Floss (N) 5

D_{max}	$U_{loss(1)} - U_{loss(2)}$
6.5452	0.0000
6.5106	0.1733
6.4996	0.2284
6.4380	0.5360
6.3690	0.8813
6.3327	1.0625
6.2538	1.4572
6.1847	1.8024
6.6385	-0.4664
5.6378	4.5370
6.4691	0.3804
5.7845	3.8035
5.8506	3.4732
6.2086	1.6833
5.9517	2.9678
6.2185	1.6335
6.1525	1.9639
5.9738	2.8569
6.4822	0.3150
7.2396	-3.4721
5.3507	5.9726
5.8290	3.5810
7.8842	-6.6946
6.5452	0.0000
5.9457	2.9976
6.1456	1.9984
6.7651	-1.0991
6.9449	-1.9984
6.1456	1.9984
6.6851	-0.6994
6.6100	-0.3237
6.3002	1.2253
6.7008	-0.7776
6.6504	-0.5258

7.8842 (Max)
[m]