Fundamentals of Engineering - Semester Design Challenge

Power Band Candy Van

ENG1101, Section #1
Design Team #2

Brooke Powell: ______________________________

Sarah Weigel: ______________________________

Holly Wilson: ______________________________

Course
Instructor

Dr. AJ Hamlin

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Department of Engineering Fundamentals
Michigan Technological University
Houghton, MI 49931

Table of Contents:

Abstract:

The purpose of this design project is to create a vehicle that has only one power source which is a rubber band. In this report are the materials which cover the information and data collected to design the power band candy van. The vehicle must be made mostly of recyclable materials, and be able to reach a distance of 20ft, using no other power source than the rubber band. Using MATLAB to convert the theoretical car into actuality. This is relevant because this code can be used for real world applications, for example furthering knowledge on “green” resources.

1.0 Introduction:

1.1 Purpose of the Report

This report analyzes the data necessary to construct a vehicle with a single rubber band for its power source. It covers the research completed to find the materials best suited to build the best vehicle possible. The goal of this research is to create a vehicle that will go a distance of twenty feet with varying payloads, in the shortest amount of time possible. This report will discuss the decision making process and describe how to reproduce the specific design of this vehicle.

1.2 Background of the Report

Before designing and constructing a power band vehicle research is helpful for choosing the optimal materials and proportions for the particular vehicle specifications. The background research shows that wheels with a larger diameter provide higher speeds. CD’s are a good choice for wheels because they are lightweight and have a large diameter; however, they have little traction on smooth surfaces. This issue can be fixed by lining the circumference of the CD with rubber, such as a cross cut section of a rubber balloon [1]. The body of the vehicle should also be as light as possible. One of the best materials for the body was acrylic because not only is it lighter than wood and more durable than cardboard, it is also aesthetically pleasing which can be considered an important criteria in the creation of a power band vehicle [2].

Another issue when designing this type of vehicle is friction between the moving parts. This can easily be reduced by applying some sort of lubrication. An easy, cost effective, lubricant is graphite powder. Which can easily be obtained by shaving a number 2 pencil [1]. Air resistance is another frictional force to deal with and can be avoided by building a frame that is narrow in width; however, a vehicle with a narrow frame makes it more difficult to travel in a straight path [3].

1.3 Scope of the Report

This report provides the necessary information to build a power band candy van (PBCV). This information includes

- Team two’s project management plan: Gantt chart.
- An analysis of the power source.
- Decision making materials: criteria table, pairwise comparison chart, and decision matrix.
- A mathematical model of the vehicle.
- The test results of the actual vehicle.

2.0 Evaluation Process:

2.1 Decision Making:

The first step in the decision making process is constructing a criteria table. By combining the design constraints and the "wants" out of the vehicle, it is decided what criteria will be considered when constructing the PBCV. Table 1 lists the criteria chosen, purpose for selection, and metric for evaluating designs for the PBCV design.

Table 1. Design Criteria Table:

Criterion:	*Why:*	*Metric:*
Ease of assembly	To assemble body quickly	Time to assemble
Lightweight	Needs to be lightweight	Weight of material base
Appearance	Looks professional, and stylish	Looks eye catching
Speed	Moves quickly across goal area	Time to finish line
Accuracy	Stays in a straight line	Distance to finish line

After considering the criteria that is pertinent to the PBCV it is important to rate the criterion by importance to the project. This is done using a pairwise comparison chart (show in Table 2).

Table 2. Pairwise Comparison Chart:

	Speed:	Ease to Assemble:	Lightweight:	Accuracy:	Appearance:	Rank:
Speed:	-	1	1	1	1	4
Ease to Assemble:	0	-	0	0	0	0
Lightweight:	0	1	-	1	1	3
Accuracy:	0	1	0	-	1	2
Appearance:	0	1	0	0	-	1

Based on the pairwise comparison, it was determined that speed was the most important criterion. The next important criteria were that the vehicle should be lightweight, followed by accuracy and appearance. Then ease of assembly was rated the least important.

The next step in the evaluation process was for each team member to come up with a design sketch. Concept sketches are included in Appendix C.

Design 1 has a long narrow body, CD's for wheels, and includes a candy storage area. The body of design 1 would be made of lightweight but stiff cardboard, the axles would be made with pencils. Hot glue would be used to attach the CD wheels to each axle.
Design 2 was designed with speed and accuracy in mind. It has the power band set up on the bottom of

the vehicle with the intention of having the payload stored on top of the frame. The wheels are proposed to be made out of CDs with the balloon tires for extra traction. The shape of the design is wide for traveling in a straight path and the frame would be cardboard which is very lightweight; however, it is not the most durable material for this type of vehicle.
Design 3 has a box shape with room for the payloads inside the vehicle. It also includes an acrylic body which would be more lightweight then cardboard or wood, and CD's for wheels with wooden axles.

In order to evaluate the individual design sketches a decision matrix was made. This was done by evaluating the pairwise comparison chart for the criteria weight percentages. The decision matrix (Table 3) was interracial in deciding which attributes to take from each of the individual designs to come up with a combined proposed final design.

Table 3. Decision Matrix

Criteria	Criteria Weight %	***Design 1***		***Design 2***		***Design 3***	
		Rating	***Score***	***Rating***	***Score***	***Rating***	***Score***
Speed	30	6	180	5	150	5	150
Ease of Assembly	10	4	40	5	50	3	30
Lightweight	25	2	50	6	150	4	100
Accuracy	20	4	80	7	140	6	120
Appearance	15	5	75	5	75	8	120
Totals:	100		425		565		520

As shown in Table 3 design two was rated the highest, and most of the final design elements were taken from those specifications. The final design consisted of a body that was long and narrow, made of tongue depressors that were hot glued together. The body was originally thought of to be made with acrylic, however, due to lack of accessibility the tongue depressors were chosen instead. The wheels were made from CD's and the axles where constructed out of the hollow piece of a pen. The power source and axles were attached to the vehicle via wall hooks that were attached to the base of the vehicle.

3.0 Design Analysis:

3.1 Elastic Analysis:

In order to gauge the effectiveness of the power source it was necessary to gather some data to calculate the amount of power that could be applied to the vehicle. In order to do this, elastic analysis of the rubber band was performed. Two rubber bands (given) were analyzed. Each band's force was determined by stretching the band 10 cm to 30 cm in increments of 5cm. To do this, the initial length of the each band was measured before it was stretched. Then, hooking one end of the band to a spring scale, each band was stretched to the various lengths and the force at each point was measured. After completing this analysis, the data helped to determine which band was the optimal choice for the vehicles power source.
The elastic analysis results had shown that band number two is the optimum choice for the power source. This was because band twos data yielded a higher percent stretch than band ones data. To proceed in the design process an equation for the vehicles power source needed to be determined. This

was done using Microsoft excel, and it was determined that the m value was equal to 0.12 and the b value was equal to 0.41. The average force vs. percent stretch was omitted from the overall analysis because the data for percent stretch of each band did not match. Due to this, a trend line as added to the data that was selected instead. The selected data (from band two only) is shown below in Figure 1.

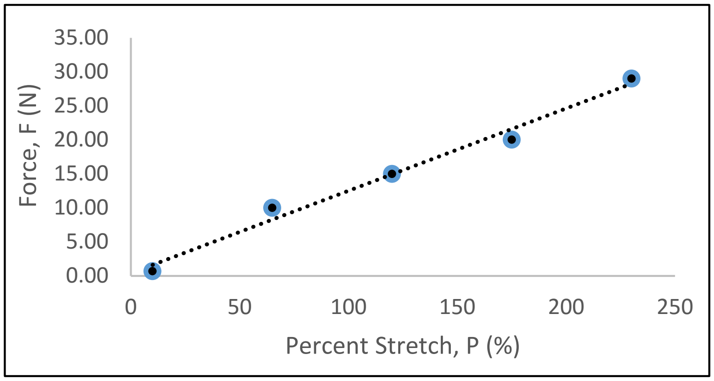

Figure 1. Percent Stretch of power band 2 as a function of force

The calculated empirical formula that was obtained is shown below:

$$F=.12P+.41$$

Where F is force in Newton's
and P is percent stretch

Finding the equation for the vehicle was important because now a prediction can be made as to how far the vehicle will go, based on its power source. This can be done without actually having to test the prototype first. Using the new found equation it was then possible to develop a mathematical model that would illustrate the vehicles ability to move based on specific design parameters.

3.2 Mathematical Model:

The mathematical model was developed by deriving numerous equations pertaining to the specific vehicle parameters. The model was developed in MATLAB, and was helpful in deciding the best dimensions for the vehicle. The parameters that were used on Team two's vehicle are listed below in Table 4.

Table 4. Vehicle Parameters:

Distance from origin to point (DOP)	0.24 m
Drive axle radius (Ra)	0.005 m
Drive wheel radius (Rw)	.05 m
Vehicle Mass (Mv)	.2211 kg
Mass of one payload, candy bar (Mp)	.0527 kg
Number of units in payload, varies	0,1,2
Band Length Unstretched (BLrelaxed)	.09 m
Band Length Stretched (BLstretch(1))	.24 m
Coefficient of static friction (μsv, musv)	0.02
Coefficient of kinetic friction (μkv, mukv)	0.01
Increment of time for numerical integration of coast phase (dt)	0.05 sec

It was discovered, in the mathematical model that team two's vehicle weighed substantially more than the suggested model was.

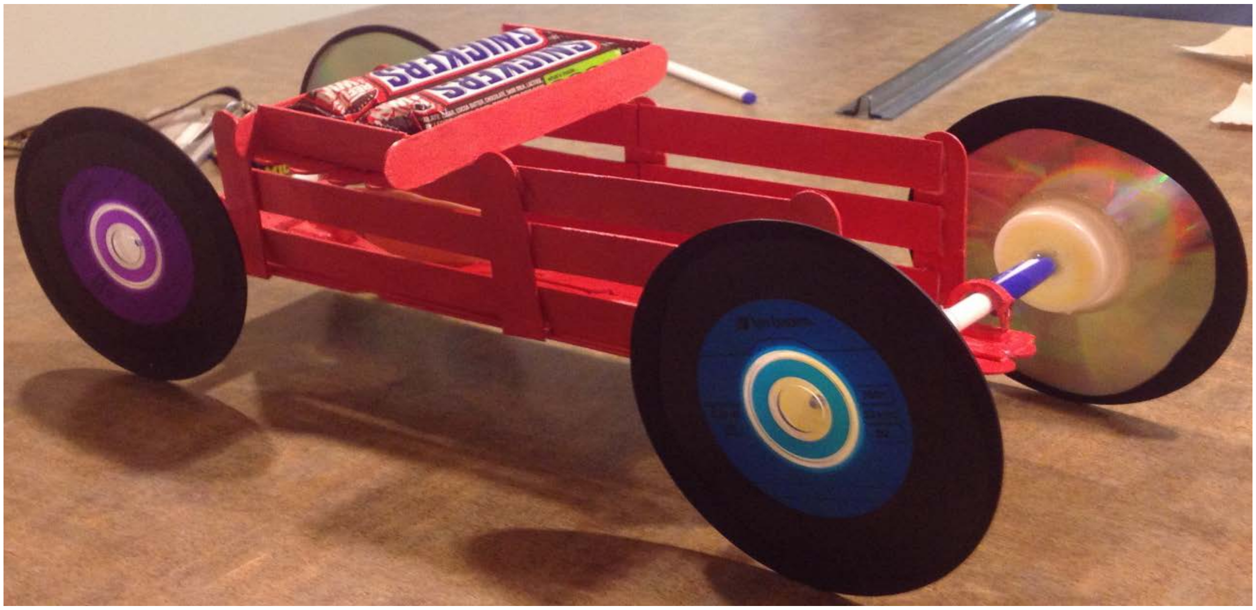

Figure 2. Final design

Using MATLAB, the mathematical model is able to predict the run times for the vehicle in question, with the different payload amounts. After the code was developed the theoretical values were replaced with the actual values from the final design parameters. This change gave varying results, shown below (Table 5).

Table 5. Actual vs Theoretical run times.

Actual Testing		Theoretical run times (s)	
Run Times (s)	Distance (ft.)	Run Times (s)	Distance in (ft.)
3.75	18	1.80	20
2.75	15	2.00	20
2.75	15	2.15	20

The reasons for the discrepancies will be addressed in the Discussion section of this report.

Finally MATLAB also output graphs of the different variables, so that it was possible to understand at what point the vehicle was shift from drive phase to coast phase. This information is important in dertermining the length to give to the string attatched to the power source. These graphs are shown in Figure 3 below.

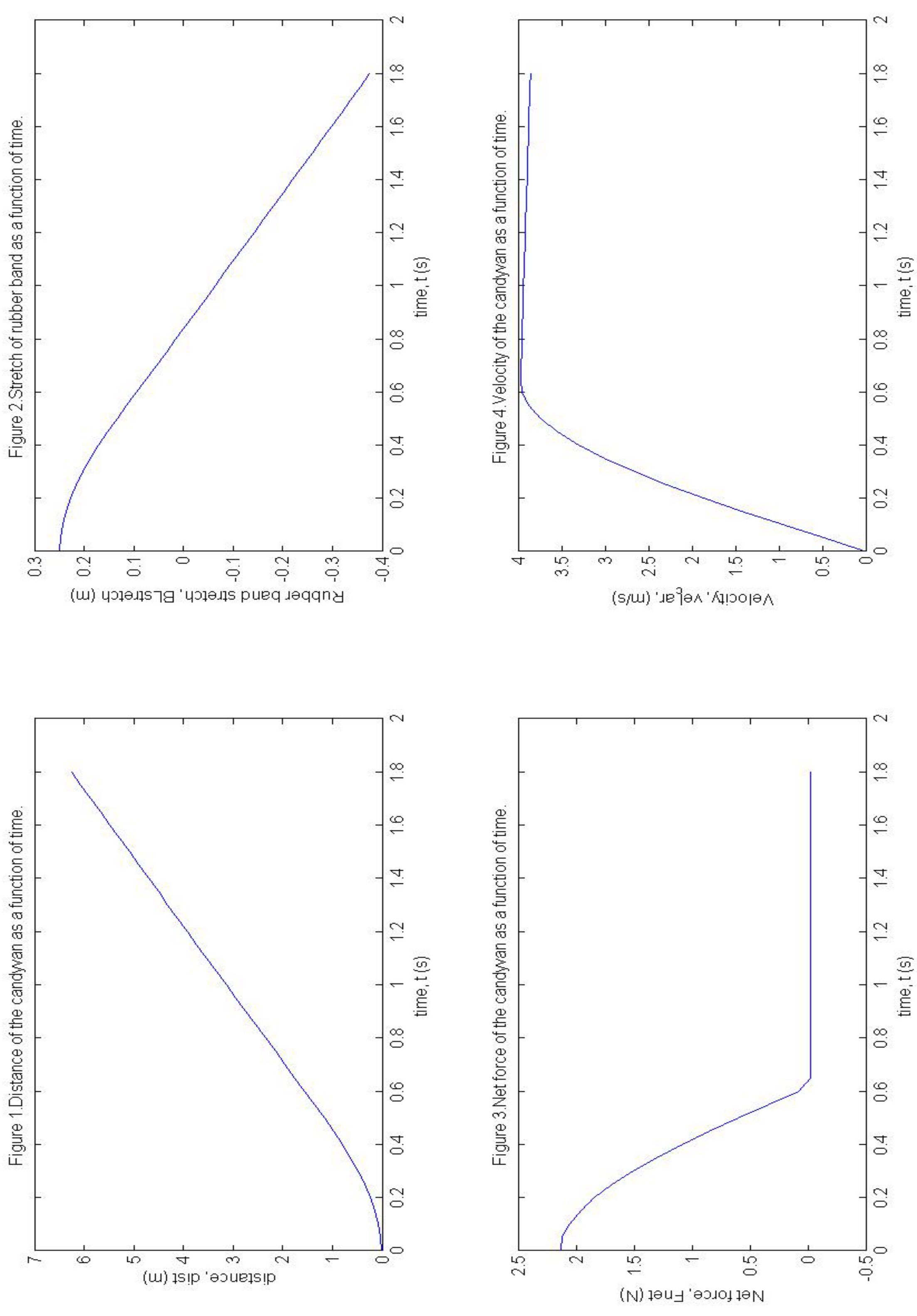

Figure 3. Graphs of predicted vehicle, distance, band stretch, velocity, and force as a function of time.

4.0 Design Demonstration Results:

4.1 Vehicle Construction:

The axles were created using regular ink pens. Each pen was taken apart and the ink was taken out of them leaving two hollow, empty pen tubes. Each tube had a pen point (with the ink removed) glued to either end. Each end of these axles was then glued to a bottle cap with a small hole punched through the middle. The bottle caps were glued to the center of the wheels which were CD's with rubber balloon "tires" wrapped around the circumference. The unused caps of the pens had the closed ends cut off and two were wrapped around each axle; each one was pushed down against a bottle cap. The purpose of this was to prevent the axles from sliding side to side while the vehicle was in motion.

Construction for the body of the vehicle was simple. For the bottom of the body, three sets of four craft sticks were hot glued together flat along the length; this created the width of the vehicle. Once each set was dry, they were glued together lengthwise by gluing the front one on top of the middle one at one-fourth of its length; the back section was glued on top of the middle one at three-fourths of its length. Four hooks were attached and reinforced with hot glue to the top of the base: two parallel with each other at the front end of the vehicle and two parallel to each other at the back end of the vehicle to hold the front and back axles in place. These hooks allow for the axles to be easily removed and replaced. The sides of the body were also created by hot gluing craft sticks together. Three half sticks were glued perpendicular to the base of the body on each side. Six sticks were glued on both sides of the bodies parallel to the base giving the sides of the body a picket fence appearance. The sides of the body not only add to the aesthetics of the vehicle, they also protect the power band and string mechanism of the vehicle. Across the top of the body, a small compartment for the payload was added. It is four sticks wide and the height was one width of a stick; just enough space to fit two payloads.

The power band and string mechanism was built by attaching and reinforcing a hook like the ones used for the axels to two craft sticks glued flat along the length. This was then glued onto the top of the base of the body right behind the front axle to allow for maximum stretch of the power band. This hook is where the power band connects to the vehicle and the power band is connected to the string with a key ring. The other end of the string is attached to the rear axle with a small piece of tape.

4.2 Vehicle Performance:

Overall, the vehicle performed well considering speed and ability to move in a straight path. One of the major concerns with this vehicle is the possibility that one of the axles would bounce out of alignment and causing the entire vehicle to turn out of the five foot wide testing area. The power band also had enough force to keep the vehicle moving a good speed. However, the vehicle was unable to make it the full twenty feet of the testing area. Without any payloads the vehicle stopped two feet behind the finish line and rolled back; this was caused by the string wrapping back around the axle the opposite way. With one payload the vehicle stopped three feet behind the finish line and with two payloads it stopped four feet behind the finish line. The final results of the performance were graded on a point system with a maximum of one hundred points. The vehicle received seventy points with points marked off due to the vehicle not traveling the full twenty feet.

5.0 Discussion:

5.1 Comparison of Math Model and Design Demonstration:

With no payloads, the vehicle took about two seconds longer than the theoretical 1.80 seconds. In the next two consecutive tests the vehicle stopped at 2.75 seconds both times which, if the vehicle would have reached the finish line, would have been at least one second slower than the 2.00 and 2.15 second theoretical times. However, the math model did a good job predicting the finishing times for this vehicle. The final design may not have completed the course due to errors in the design and chosen materials.

The math model was created before performing last minute adjustments to the vehicle; this may be the reason why the performance times were off. After the performance, the math model showed that the vehicle's friction coefficient was different than the original. This was most likely due to the added friction on the axles after the addition of more weight. Another difference between the math model and the design demonstration was that the actual string length was longer than the one added to the model because the string length was increased shortly before the test. The car length was also decreased slightly after putting the dimensions in the math model; this may have inhibited the amount of stretch allowed for the power band.

5.2 Possible Sources of Error:

The major problem with this vehicle is how the string wraps back around the axle causing the entire vehicle to stop its forward movement and move backward. Different string lengths were tested, but, no matter what the length was, the same problem still happened. The most likely cause for this is the thickness and stiffness of the string. Once the power band reached its unstretched length the string became slack and folded in on itself causing it to wrap the opposite way around the axle. This error may have been avoided if the string was thinner because it would be less likely to fold in on itself when it becomes slack.

Another source of error for this vehicle is the amount of friction on the axles. The vehicle slowed down dramatically with each added payload because of the added weight and friction on the axles. A possible solution for this problem could be the addition lubricant on the hooks to reduce the amount of friction from the weight of the body on the axles.

6.0 Conclusions and Recommendations:

Our design performed well, but did not manage to fully complete the testing challenge. Our vehicle stopped shortly before the finish line on all test runs. In hindsight, we should have extended the power band and string length to provide more propulsion force. This would have been slightly difficult to accomplish. The vehicle would have to be extended, and then weight would have to be recalculated.

Most elements of the candy van were convenient and worked well. The design met all of the specifications, such as portability, cost, and sustainability

7.0 References:

[1] “Mousetrap car instructions,” http://www.docfizzix.com/topics/construction-tips/Mouse-Trap-Cars/ Accessed February 11, 2014.

[2] “Rubber-band-powered car,” http://www.instructables.com/id/Rubber-Band-Powered-Car/ Accessed February 9, 2014.

[3] “The inventor’s challenge—build and race a car propelled by rubber bands,” http://www.kidspacemuseum.org/node/9596 Accessed February 7, 2014.