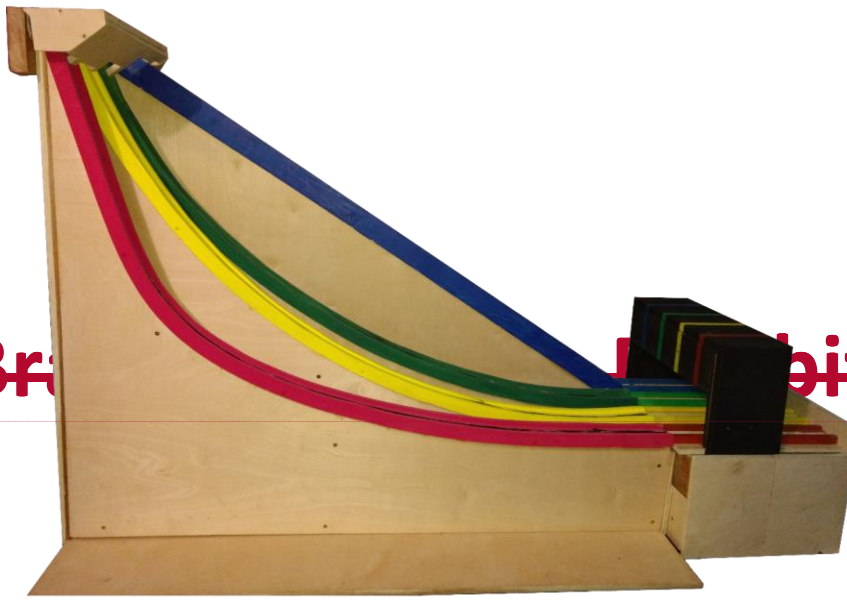
Brachistochrone Exhibit



Path of Quickest Descent

Humboldt State University

Engineering 215: Introduction to Design, Fall 2017

Project for The Redwood Discovery Museum

Designed by Team Schmotron:

Chris Fabbri
Daniel Hodges
William Nitzsche
Juan Sanchez

Formatted: Font: 46 pt, Bold

Formatted: Space After: 6 pt

Table of Contents

Table of Figures

Table of Tables

1 Problem Formation

1.1 Introduction

Included in Section 1 is Team Schmotron's objective statement which outlines and explains the solution to the problem presented by the client, The Redwood Discovery Museum. A black box model, seen in Figure 1-1, is used to project the impact that the project has on the world. The Redwood Discovery Museum, located in Eureka CA, is geared towards presenting scientific knowledge in a fun and engaging way to children of all age groups. The client required a functional demonstration of the Brachistochrone question and has contracted Team Schmotron of Humboldt State University's Engineering: Introduction to Design Fall 2017 class to design the exhibit.

1.2 Objective:

The objective of this project is to design and build a functional Brachistochrone exhibit and present the concept in a fun and educational method; while maintaining a sturdy, child-safe structure that is both aesthetically pleasing and engaging.

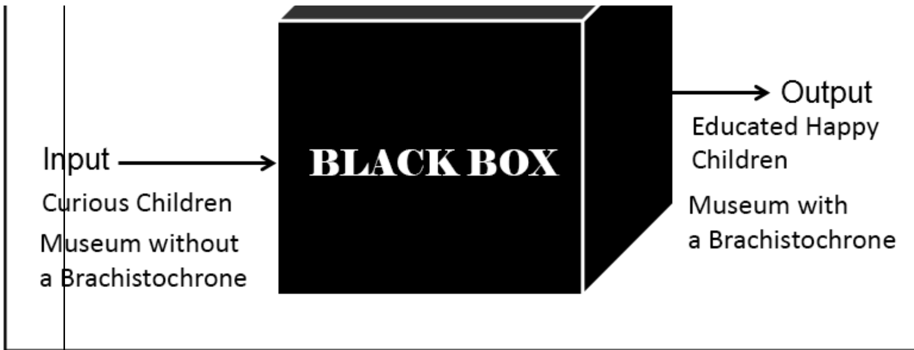


*Figure 1-11-1: **Black Box Model** The input is the design objectiveproblem to be addressed, the black box is the design and output is the effect of the solutionn on the world. – Created by Chris Fabbri*

2 Problem Analysis

2.1 Introduction to Problem Analysis

This problem analysis section provides a method to investigate~~, and~~ analyze, and finde a final solution to the problem ~~project~~ defined in the objective statement. Specifications will be stated and their relating minimums and maximums will be established. Any additional considerations will be ~~stated~~ discussed in this section. The client mandated criteria and constraints will be established as well as the comparative importance of each ~~criteria~~criterion using~~via~~ a weighting system. The estimated usage of the project will be predicted and the planned production volume will be addressed.

Commented [WN1]: Think the bottom part might need rewording.. ..is our objective statement a problem statement?

Commented [WN2]: Specifications of what? Max's and mins of what? Kind of vague, I know its discussed in detail below, but maybe a little context could make it sound smoother.

2.2 Specifications

~~2.2~~ Supplied constraints given by our client that we must adhere to.

Formatted: Normal

The specifications of this project include:

- Project must be moveable.
- All parts must be larger than choking hazard size.
- Must not include an interactive ~~a~~ digital screen of any kind.
- Must be a 'table top' style project that does not require wall support.
- Must fit through a standard door frame.
- Total investment must be ≤ $5~~6~~00.
- Must be sturdy and safe for young children.

Commented [WN3]: 600 or 500?

2.3 Considerations

There are several topics that must be taken into consideration when designing this project, they include:

- Wheelchair accessibility.
- Anti-theft measures – make it difficult for children to pocket components.
- Unattended children.
- Ease of repairs.
- Use by multiple age groups.

2.4 Criteria

2.4.1 Introduction

The criteria, constraints, and weights provide a method of assessing and measuring the overall goals and quality of the project. The ~~criterias~~criteria consist of the most important factors specified by the client to insure a~~the~~ high quality exhibit~~of the project~~. The constraints are a way of measuring the success of the implementation ~~implantation~~ of each criterion. The weights range from 1-10, 10 being the most important and 1 being of little to no importance, this weighting system~~it~~ is used to prioritize the importance of each criteria. The criteria~~'s~~ constraints, and weight of importance~~, and specifications~~ are illustrated in a table in section 2.4.2 below.

2.4.2 Criteria, Constraints, Weight

Table 1: Criteria, Constraints, ~~Wieghts~~Weights

Criteria	Constraints	Weight (range from 1-10)
~~Weight of Final Product~~Safety	~~Light enough that 2 adults can move it, heavy enough that multiple 3-year old's can't tip it~~Sturdy construction, can not be easily tipped, no choking hazards.	10
~~Overall Size~~Movability	~~Larger than 3'x3'x2', small enough to fit through doorways.~~Movable by two people, can fit through doorways.	10
Cost	Client requires > $150 ≤ $~~600~~500	6
Construction Instructions	Easy to follow instructions for someone with minimal electronics experience.	6
~~#~~ Number of Tracks	Must be ≥ 3 ~~and ≤ 7. More is better.~~	8
Aesthetics	> Looking homemade.	5
Up-cycled Material	> 10%	5

Formatted Table

Commented [WN4]: 500 or 600?

2.4.3 Description of Criteria

Formatted: Heading 4, Indent: Left: 0", Hanging: 0.6"

Formatted: Heading 3

2.4.3.1 ~~Weight of final product~~Safety

Formatted: Heading 4

The ~~criteria~~criterion~~!~~ for the ~~physical weight~~safety of the final product is~~was~~ ~~composed of~~ a combination of sturdiness and choking hazards~~afety and mobility~~. The~~Our~~ ~~clients~~client's main concern with all of their exhibits, ~~now~~current and future, is the safety of children. The~~If an~~ exhibit ~~is~~ needs to be sturdy ~~heavy~~ enough to where a child can't move it or cause it topple over~~topple it, it is that much safer and will most likely increase the exhibits longevity~~. But not to heavy where it interferes with the movability criteria.~~if it's too heavy t~~ The exhibit also needs to be free of choking hazards~~o where it can't be easily moved or transported, to where it becomes a burden on the client~~. This is why the design uses golf balls and hot wheel cars, because they are all above the choking size diameter.~~, thus~~This is why our client weighted ~~this criteria~~this criterion at a ten.

2.4.3.2 ~~Overall size~~Movability

Formatted: Heading 4

~~Our client is all about projects and exhibits that make children and adults alike say to themselves "whoa, what's that?" This type of response~~ increases the appeal of such exhibits ~~or products~~. ~~For our specific project~~The criterion for the overall size is comprised of mobility and accessibility. The~~, our~~ client thinks that ~~the larger the~~a larger sized design is better with the idea of increasing the time a vehicle slides down the ~~b~~~~Brachistrochrone's~~Brachistochrone track, which in turn will also ~~bringing up~~increase the excitement and appeal of the exhibit. ~~But again tying into the with the previous criteria the want to~~ K~~k~~eeping the movability of the exhibit ~~high~~practical is also important when considering size, thus the constraint that it must be able to fit through an average door frame. The overall size must be able to be carried by at least two people. This is very important to them with ~~again~~ a weight of ten.

2.4.3.3 Cost

Formatted: Heading 4, Space Before: 2 pt

~~This criteria was very easy for the client to come by, they would ideally~~The client expects us to use more than $150 to ~~better~~encourage higher ~~ensure that the product isn't created too "cheaply"~~quality, but limited us to the~~-~~ maximum amount ~~the amount~~ of funding ~~we already have~~ available, which is $~~6~~500. ~~Not too worried about this criteria the scaled its~~As long as total cost lands somewhere in this range th~~e~~an it will be acceptable, thus the importance ~~to a~~weighted to 6 out of 10~~ten~~.

2.4.3.4 Construction Instructions

Formatted: Heading 4, Space Before: 2 pt

The client specified that they want replication ~~would love~~ instructions on how to build another similar ~~b~~Brachist~~r~~ochrone based off this design ~~like the one thee Schmotrons~~~~based on this project~~. ~~are designing~~This is due to the ~~with the~~ consideration that they couldn't find one anywhere in Humboldt. They just want to make sure that the instructions include more ~~easily followable~~user friendly instructions than those given by IKEA's products.~~,~~ T~~t~~his criteria also ~~too~~ received a weight of 6 out of ten.

2.4.3.5 Number of tracks

Formatted: Heading 4, Space Before: 2 pt

This is one of the more important aspects of our product to the client. ~~Simply stated by them that is~~The project must have 3 or more tracks demonstrating different curves, with no upper bound.

2.4.3.6 Structural Aesthetics

The structural aesthetics of our project were just constrained at “it just can’t look like it was slopped together or too homemade” with the importance of the criteria~~l~~ being a ~~five~~5 out of 10.

2.4.3.7 Up-~~scaled~~cycled material

With the spirit and green i~~I~~deals of HSU and the Redwood Discovery Museum, our group~~,~~ and the client came up with the criteria that the project would consist of at the least ten percent up-cycled materials. There is no upper bound and the more up-cycled materials used the better. With this not being their top priority, they weighted it ~~at a~~at 5 out of 10~~ten~~.

2.5 Usage Amount

~~2.5~~ The amount of use could vary depending on~~ any~~ layout changes of the building, how much play with it~~interactions of the children~~, and number~~volume~~ of future exhibits. It’s~~We are~~ predicted~~ing~~ not be cycled out for other exhibits very often. Since the Brachistochrone is a general physics topic, it will likely never leave the floor, since no other exhibit will demonstrate this phenomenon. This creates the assumption that it will have continual and year round use. ~~We are predicting h~~Heavy daily use is multiple age groups of children due to the excitement of the ‘race track’ nature of our exhibit. ~~We~~ of all age groups are also predicted to use the exhibit as intended and race objects down its many tracks. ~~We also expect~~ T~~t~~he design might also have~~to have many~~ more uses from~~that the~~ creative ~~group of~~ children who might ~~will~~ find~~, such as~~ a Tautochrone,~~ in~~ which is where projectiles fall from different areas and finish at the same time. Since the Brachistochrone is dependent on the exact cycloid curve, the track angles will need to withstand constant use. Since the exhibit uses a standard measurement of mathematical theory (line of quickest decent) it can be a very reliable example if it can withstand the years of abuse. The durability to daily use will be a huge factor in the value of the exhibit and its role in the museum as a reliable educational exhibit.

Formatted: Heading 4, Space Before: 2 pt

Formatted: Heading 4, Space Before: 2 pt

2.6 The amount of use could vary depending on future changes of the building layout, and interactions of the children, and volume of future and new exhibits. We are predicting that due to the large size of our exhibit that it will not be cycled out for other exhibits very often. Creating an assumption of its continual and year round use Therefore, it is possible that it could receive year-round use. We are predicting heavy daily use by multiple age groups of children. Due to the excitement of the 'race track' nature of our exhibit we predict that the majority of daily visitors will engage in use. We expect children of all age groups to use the project as intended and race down objects down its many tracks, but use can also be expected to use the tracks as ramps dependent on the slopes of the tracks. We also expect the design to have many more uses that the creative group of children will find.

We expect tThe production volume is expected to be aA single, large, sturdy, Brachistochrone exhibit that will be produced for useto be used at the Redwood Discovery Museum. A prototype of multiple track ideas and finish line placement mechanisms will be produced prior to the final exhibit. Instructions on how to build a near iIdentical product will be included as per the clients criteriain case of the clients product wants.

2.7 Literature Review

2.8 The following sections provide information retrieved while researching possible related topics to constructing a Brachistochrone exhibit.

2.8 Brachistochrone

2.9 This section describes the definition of a Brachistochrone, while also explaining some of the mathematics behind each associated curve associated as well. It is also explainsIn addition to explaining some basic construction techniques tofor each component that may be used in the construction of the final solution. Child safety and development was also researched since they our targeted age is from 3-8.

2.9.12.8.1 Definition of Brachistochrone

The Brachistochrone, derived from Greek words, Brachi -meaning 'short' and Chrone meaning 'time', is the concept of finding the fastest distance curve of travel from a point 'A' to a point 'B' where 'A' is located above 'B' (Parnovsky, 1998). The idea was to provide proof that the quickest way between two points becomes a curve rather than a straight line when gravity and accelerationonly the acceleration due to gravity are applied. This is, also known as the a curve withof fastest decent. The Brachistochrone is modeled as a particle moving along a curve with gravity being the only force applied to its acceleration;, and friction due toof the path is negated.

Commented [CTF5]: Section 2.1 done by Chris

~~2.9.2~~2.8.2 Math Behind Brachistochrone

~~2.9.2.1~~2.8.2.1 Single Solution to Brachistochrone

In 1696 famed mathematician Johann Bernoulli issued a challenge to other brilliant mathematicians calling for them to discover a solution to the Brachistochrone problem. Isaac Newton, Jakob Bernoulli, Gottfried Leibniz, and Guillaume de l'Hôpital were all able to show mathematically that the optimal solution to the problem was a segment of a cycloid curve. (Brookfield, 2010) See ~~figure~~ Figure 2-1 ~~2.1.1~~ example of the difference in time 3 types of paths take. The cycloidal path is a further distance, but takes less time compared to a straight line.

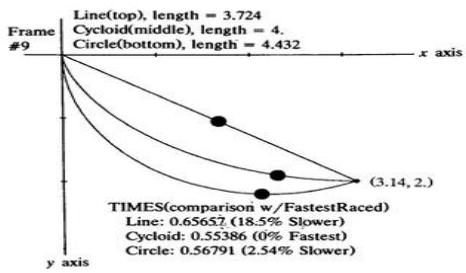
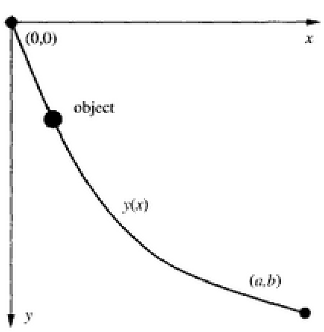


Figure 2-1: Time vs Curve This simulation generated from Mathematica helps to express the difference in time by taking a path modeled from a line, cycloid, and circle. (Haws, 1995)

~~*Figure 2.1.1: Time vs Curve This simulation generated from Mathematica helps to express the difference in time by taking a path*~~

~~2.9.2.2~~2.8.2.2 Example of a Mathematical Approach

Several solutions to the Brachistochrone have been presented throughout time, one such solution is as follows:



$$T[y(x)] = \int_{(0,0)}^{(a,b)} \frac{\sqrt{dx^2 + dy^2}}{\sqrt{2g\,y(x)}} = \frac{1}{\sqrt{2g}} \int_0^b \left[\frac{1 + (dx/dy)^2}{y(x)}\right]^{1/2} dy$$

Figure 2-2: An example curve and solution equation. The notation T[y(x)] describes an integral that takes a function y(x) as an input and returns a number T as an output. T represents time and y(x) is the equation of the curve. (Johnson, 2004)

Figure 2.1.2: An example curve and solution equation. The notation T[y(x)] describes an integral that
The Brachistochrone model with solutions based on partial cycloid curves makes an appearance in real world engineering most notably in sporting applications. In order to break world records the idea of the shortest time instead of the shortest path becomes very important. Ski jumps, bike jumps, half pipes, and, luge track design are some of the fields that are starting to incorporate the Brachistochrone curve. In 2011 artist Raphaël Zarka created a cycloid skateboard ramp in an attempt to blend art, physics, and sports. (Perfoma, 2011)

2.102.9 Examples of Brachistochrone's

2.9.1 Simple Examples

The simplest example of a brachistochroneBrachistochrone device is two ramps side by side. while the other is a cycloid curve. A simple rolling projectile is used such as a marble or bearing. Two marbles are released at the same time and the person can observe the marble on the cycloid curve reach the endpoint quicker than the linear slope. In the picture below a brachistochroneBrachistochrone an adjustable linear slope ramp so the user can test multiple intersections of the two types of ramps. Simple Brachistochrone designs can be found on CAD file sharing communities.

The simplest example of a brachistochrone device is two ramps side by side. One ramp in a linear slope while the other is a cycloid curve. A simple rolling projectile is used such as a marble or bearing. Two marbles are released at the same time and the person can observe the marble on the cycloid curve reach the endpoint quicker than the linear slope. In the picture below a brachistochrone is shown with an adjustable linear slope ramp so the user can test multiple intersections of the two types of ramps.

Figure 2-3:Brachistochrone device made by a 3D printer design. Open source CAD design from Makerbot's Thingiverse online community.

2.9.2 Complex Examples

More paths can be added in order to illustrate different mathematical curves similar to cycloid. Mathematical curves that could be used along alongside cycloid are parabolic, circular, 6th degree

Commented [CTF6]: Section 2.2 created by Daniel

Formatted: Heading 3, Space Before: 2 pt

Formatted: No bullets or numbering

Commented [c7]: Need to come back and add web address

Formatted: Heading 3, Space Before: 2 pt

polynomial, and a line. This way a child can observe different curves in math while observing the brachistochroneBrachistochrone phenomenon. So moreMore paths can give a better understanding about the bell curve nature of the cycloids path and speed of a projectile. If the slope is not enough it will be too slow, if the slope is too great it will be slow due to the increased horizontal portion, Itit will be the curve of the cycloid that will win the race.

More paths can be added to show more examples of paths that will not beat the cycloid path. If a path is more steep in the beginning than the cycloid, it will not finish quicker, as one would think. So three paths can give a better understanding about the bell curve nature of the cycloids path and spread of a projectile. If the slope is not enough it will be too slow, if the slope is to0 great it will be slow. It will be the curve of the cycloid that will win the race.

Figure 2-4: An example of what mathematical curves can be used alongside the cycloid curve. Including parabolic, circular, 6th https://www.maa.org/sites/default/files/images/convergence/AnimatedGIFs/Race/frame_01.gif

2.2.2 On January, 2017, Mythbusters Adam Savage designed a brachistochroneBrachistochrone for the science youtube channel Vsauce which proved to be a good example of a brachistochroneBrachistochrone. After a slow motion analysis, it was observed that of the 3 balls dropped, the ball on the cycloid path reaches the end the quickest. Savage used three paths for rolling projectiles; a circle curve at 90 degrees, a cycloid, and a linear line. It would have been good to see a parabolic curve on there as well working with such a famous engineer.

Commented [c8]: Need to come back and add web address

2.11.12.10.1 Lines

One of tracks we will be designing in the Brachistochrone is a straight line. It is known that the shortest distance between two points is a straight line. The equation of a line is $y = mx + b$. Where *m* is equal to the slope of the line. It is unclear what our slope will be, but it will be negative since the balls are starting from the top and rolling downwards. The slope will be determined once we have established how long the entire track is going to be. The longer the track means that slope will be shorter, and a shorter slope means less velocity.

2.11.22.10.2 Circles

A segment from a circle will be used as another track. The equation of a circle is $R^2 = x^2 + y^2$. Where *R* is the radius of the circle. The radius will be determined when we know how long the track is going to be. This is of great importance because we need the circle to be a good circle, not just a bad one, but a really good one. It is almost like an ellipse but not really because ellipses are like circles that have been stretched out a little bit.

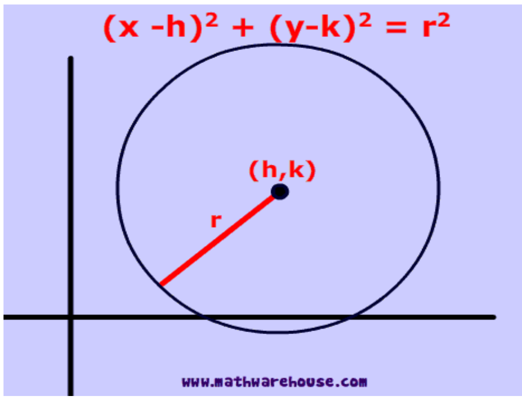


Figure 2-5: Shows the equation of a circle and demonstrates that the larger the radius, the bigger the circle.
www.mathwarehouse.com

~~*Figure 2.2.4: Shows the equation of a circle and demonstrates that the larger the radius, the bigger the circle.*~~

A parabola will be used in our tracks and they can be described mathematically by the equation $y = x^2$. This pathway will be useful because it can be very steep and develop acceleration quicker than the other pathways. Parabolas were originally thought to have been the answer to the Brachistochrone equation, but it turned out not to be the answer to it.

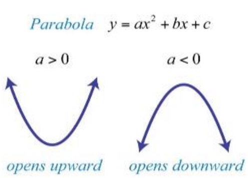


Figure 2-6: Shows the equation of a parabola. https://study.com/cimages/multimages/16/parabfocdir2.jpg

~~*Figure 32.2.5: Shows the equation of a parabola*~~

Cycloids will be used because the answer to the Brachistochrone equation was an equation of a cycloid. These equations have a parametric equation of $x = r(\theta - \sin\theta)$ and $y = r(1 - \cos\theta)$. Looking at the cycloid it appears to be similar to a circle, however, it can be seen that is steeper at the beginning of the decent giving it a faster velocity then the other. It also doesn't level out as quickly as the other curves, giving it even more velocity. This will prove to be the fastest of all the tracks that are built.

~~2.12~~2.11 Basic Construction Techniques

Commented [CTF11]: Section 2.4 done by Chris

~~2.12.1~~2.11.1 Types of Table Bases

There are 7 very common table bases. These include legged bases, trestle bases, three types of pedestal bases, wall mounted bases, and T-shapes bases aka end-bases. These bases can be constructed from wood, metal, or high strength plastics.

Figure 2-7: Examples of Table Bases From left to right: T-Shaped, Tripod, Round Plate, X-Shaped, Wall Mounted. www.maxsungroup.com/table-bases-guide-find-ideal-table-base-restaurant/

~~2.12.1.1~~2.11.1.1 Legged Base

Legged bases are the most common table base, typically consisting of 4 legs extending from each corner of a square or rectangular table.

~~2.12.1.2~~2.11.1.2 Trestle Base

Trestle bases are a cross between legged bases and T-shaped. Trestle tables are extremely sturdy and can last a very long time (Countryside, 2016). Trestle bases can vary quite a bit in design, but they typically consist of 4 legs extending from the corners, the two legs on each end of a rectangular table are then connected with a trestle. Sometimes a third trestle is used to connect to two trestles to each other at the middle of each trestle. Another common trestle base consists of two T-shaped bases at either end of a rectangular table which are then connected together in the middle of the T using a trestle. See Figure 2-8 for a visual.

~~Trestle bases are a cross between legged bases and T-shaped. Trestle bases can vary quite a bit in design, but they typically consist of 4 legs extending from the corners, the two legs on each end of a rectangular table are then connected with a trestle. Sometimes a third trestle is used to connect to two trestles to each other at the middle of each trestle. Another common trestle base consists of two T-shaped bases at either end of a rectangular table which are then connected together in the middle of the T using a trestle. see figure 2.2.2 and 2.2.3 for a visual.~~

~~**Figure 2.2.2: Trestle Table** (Countryside, 2016) **Figure 2.2.3: Trestle Table** (White, 2012)~~

Formatted: Caption

~~2.12.1.3~~2.11.1.3 Pedestal Base

Pedestal bases originate from the center of the table and extend down to the ground, they can terminate into an X shaped bases, tripod shaped bases, or square/round flat bases. Round plate bottom pedestal bases are optimal for round top tables. The ~~X-shaped, square plate, and trip~~od bases are optimal for square table tops. See Figure 2-7 ~~figure 2.2.1~~ for visuals.

Figure 2-8: Trestle Table (Countryside, 2016)

~~2.12.1.4~~2.11.1.4 *T-Shaped Base*

A T-shaped base typically looks like an inverted 'T'. For long rectangular tables, it is recommended to use two T-shaped bases at either end of the table. For extra-long tables, or for extra durability, a third T-shaped base can be added to the middle of the table. See Figure 2-7 ~~figure 2.2.1~~ for visuals.

~~2.12.1.5~~2.11.1.5 *Wall Mounted Base*

Wall mounted table bases work best with square or rectangular table tops. They require a wall to be affixed to, and are not moveable once installed. See Figure 2-7~~figure 2.2.1~~ for visuals.

2.11.2 Working with Plexiglas

~~2.12.2~~ This section provides information on cutting and bending of Plexiglas.~~ – Bending and Forming~~

2.11.2.1 Cutting Plexiglas

Plexiglas can be difficult to cut, careful measures must be taken to achieve a clean cut and to cracks. A common method used to cut sheets of Plexiglas is the score and snap method. Carefully measure and make when you wish to cut. Secure a straight edge to be used as a scoring guide along your marked line. Score the Plexigla~~s~~s by running a utility knife along the straight edge, deepen the score by repeating 5 times or more. Leaving the straight edge firmly secured to the Plexiglas, move one end so that is hanging off a table. Firmly and evenly press down on the part hanging off the table and the Plexiglas should cleanly break along the scored line (Davenport, 2009). Using a Dremel with a cutting tool is also recommended for a more reliable cut. Set the Dremel at a low speed to avoid burning the Plexigla~~s~~s and proceed to cut almost all the way through, then press down firmly and evenly to snap the remainder off. (Reid, 2011)

~~2.12.2.1~~2.11.2.2 *Bending Plexiglas*

Plexiglas can be easily bent using common household tools. A simple bending jig can be constructed from clamps and pieces of wood or metal (see figure 2.2.3). Plexiglas can be bent by applying heat from tools such as a butane kitchen torch, heat gun, or salvaged heating element from a toaster oven.

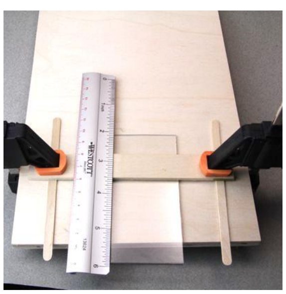


Figure 2-9: Bending Jig A simple bending jig created from 2 clamps, a piece of wood as the straight edge, and 2 pieces of wood the same thickness as the Plexiglas as spacers. (Shepherd, 2017)

~~**Figure 2.2.3: Bending Jig** A simple bending jig created from 2 clamps, a piece of wood as the straight edge, and 2 pieces of wood the same thickness as the Plexiglas as spacers.~~

~~2.12.2.2~~2.11.2.3 Forming Plexiglas

Plexiglas can also be easily formed into many shaped by uniformly heating an entire sheet and then placing it on to a mold. The Plexiglas sheet needs to be heated to a temperature between 290°F to 350°F, optimal forming temperature is around 325°F. At this point it becomes the texture of a piece of bologna and is easily formed over a mold. Allow the Plexiglas to cool and harden, but remove from the mold when it still warm. Avoid overheating the Plexiglas as this can lead to fingerprints, glove marks, or dust attaching. Avoid leaving the Plexiglas at forming temperatures for extended amounts of time as this can lead to edge degradation. (Arkema, 2006)

~~2.13~~2.12 Track Materials

These materials~~,~~ must be durable materials that can be used to create a track for an object to ride on and withstand use by children.

2.12.1 Building Materials

2.12.1.1 Woods

Woods are great building materials they are cheap, extremely durable and easy to attain, because "wood has a high ratio of strength to weight and a remarkable record for durability and performance as a structural material" (Forest Service, 1974)~~(Wood)~~. Another great quality and characteristic of wood is that it can easy be manipulated and easy changed into any shape you want to achieve. They are mostly non-toxic and relatively light compared to certain metals.

2.12.1.2 Stones

Stones are the most durable building material one can use to build any sort of structure. Just think how the pyramids have lasted so long, when building made from metal rust, bend, or become unstable. The answer lies that when one uses metal they tend to use the most minimal amount and use hollow pieces of metal for support; When using metal humans tend to build structure that don't have hollow stones or leave too much space ~~open(~~open (ELI5 ,2016).

2.12.1.3 Metal

The reason behind the immense use of metal as a building material is contributed to is malleability. Metals are unlike any other strong material. Metal is like an extremely strong dough. It can be baked and hardened, rolled out thin, reshaped, or even be turned back to the original "dough" (Elliott, 2005~~Malleability, Anderson~~). This means that metals can be shaped, then reshaped when one doesn't get the results they want.

2.12.2 Types of Projectiles (Balls and Cars)

2.12.2.1 Aerodynamics and Speed

The speed of a projectile is directly related to the distance that object travels, divided by the amount of time it takes to get from point A to point B. Each vehicle will have the same distance to travel and will take each curve a different time to reach point B. The only speed used in a Brachistochrone is its acceleration due to gravity ~~correlated~~ to the speed of an object and its acceleration to that speed. For this specific reason one sees that most sports cars have a streamline profile. This increases the lift of the car reducing is friction against the road, and reducing the drag the affects the vehicle. Although

Commented [c12]: Section 2.5 created by Juan

Formatted: Heading 3, Space Before: 2 pt

Formatted: Heading 4, Space Before: 2 pt

Formatted: Heading 4, Space Before: 2 pt

Formatted: Heading 3, Space Before: 2 pt aerodynamics plays a massive role in the speed of an object, in speed of less than 100 miles per hour, the difference aerodynamics plays on an objects speed is considered ~~negligible(~~negligible (Building Speed, 2017).~~.~~

2.12.2.2 Spherical Projectiles Over Streamline Projectiles

When testing the effects of gravity, drag, and lift of a vehicle, When testing the effects of gravity, drag, and lift on an object one needs to rely on one single factor to maintain a consistent testing base. This factor is the object(s) center of gravity. If this factor isn't consistent then all the trials one runs trying to prove how the effects of gravity, lift, and drag play on an object. Objects that are spherical tend to have a huge consistency with their center of gravity being right in their center, this is due to having that center equidistant from all that spheres sides creating a great test object. Streamline objects are slightly trickier, for example a car. Cars tend to have their center of gravity either just in front of their rear axle, just behind their front axle, or just behind the driver's butt. causing an inconsistency in ~~trials(~~trials (Building Speed, 2017~~safety~~).

Formatted: Heading 4, Space Before: 2 pt

2.13 Simultaneous starting mechanisms

Commented [c13]: Section 2.6 created by Juan

Methods of simultaneously launching all 4 vehicles.

2.13.1 Mechanical

Formatted: Heading 3, Space Before: 2 pt

Mechanical mechanism to release objects at the same time on a track vary slightly in the actual design but are virtually all the same. The Idea behind these Mechanism is to release the objects being raced on the track at the same time have a consistent and fair environment in which the objects can be tested for their speed and acceleration. These mechanisms are made and implemented to reduce delays in release or uneven releases caused by Human error. The most common type of mechanical release mechanism uses a pin to hold the object and stop it from rolling down the track and reaching the end of the track before it's supposed to. These pins are connected to a "trigger" that is held against a resisting force such as a spring or a rubber band. Once the trigger is released the rotating arm holding the pins in place will pull down pulling the pins with it releasing the held objects. This mechanism is the most common due to its easy set up, and non-electrical powered structure (Pack, 2009 ~~1~~).

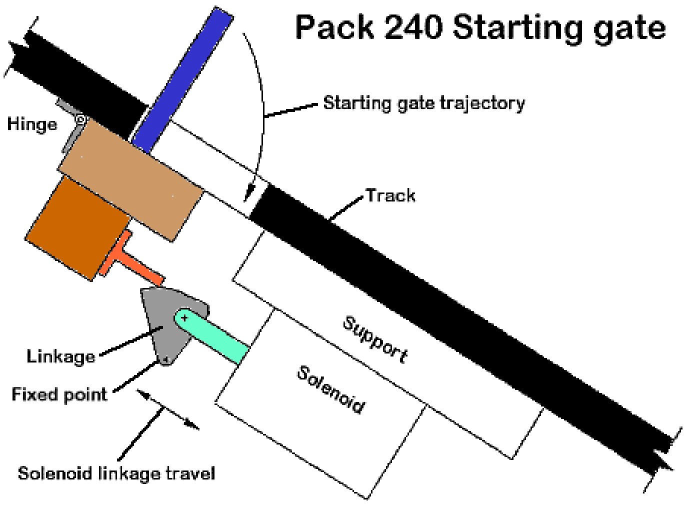


Figure 2-10: http://www.oocities.org/heartland/plains/8340/start.htm

Figure 2.6.1 http://www.oocities.org/heartland/plains/8340/start.htm

Electrical Mechanism rely on a computerized chip to release the object that is being raced down the track. When it comes to time of testing the speed and efficiency of the object in question, one presses a button. Upon the insertion of the said button a circuit is completed signal the mechanism to drop the doors that were set in place to stop the object from releasing its kinetic energy and propelling forward toward the end of the track. This mechanism extremely accurate and is powered by electricity, therefore it can't be operated without power.

2.14 Finish Llline pPlacement mMechanism (iIndicator mMechanism)

Formatted: Font: Bold

Commented [c14]: Section 2.7 created by Juan

2.15 Finish line placement Mechanism for toy tracks are a key component when racing two objects cars. To know which car or object reached the end of the track first in the community of what seems be a tie, one needs to use and finish line placement mechanism to determine a clear winner. On these different methods of being able to track a winner (pun intended) three stand out the most, one1 mechanical, and the other two electrical.

2.14.1 Mechanical

Formatted: Heading 3, Space Before: 2 pt

The Mechanical finish line indicator uses an arch over the end of the track that the objects are On the arch is a simple axle that is ran through the top of the arch, on this axle one hangs some sort of barrier that thangs to the bottom of the track on all lanes. Each lane with its own separate barrier. As the objects roll down and cross the finish line each separate lane with have the barriers move and lock all the other barriers in place, displaying a clear winner. Displayed in figure 2.7.1 below(below (C, 1970)..

Figure 2-11: www.racehotwheels.com

Figure 2.7.1 www.racehotwheels.com

2.16 There are two electrical methods that will be used to determine which object crosses the finish The first method is used on professional racecars tracks as well as toy car competitions for its accuracy and acceptance of the results rate. This method is a multi-frame slow-motion camera. This method uses a camera strapped to the end of the track that watches the exact point where the finish line is placed, this way the footage can be reviewed by a group of judges and a clear winner can be chosen. The other electrical method relies on the use of a programmable chip, and infrared lasers that are projected across the end of the track. Whichever lane breaks or trips the connection to the end of the track first, triggers an immediate indicator to bring attention to the winning lane, such as a light, a buzzer or both, to indicate the winner of that specific race set. This method is also probably the cheapest to build and maintain if one already has the coding skills (Patent, 2004).The two electrical methods for an end finish

2.182.15 Child Safety Standards

2.15.1 Choking

Choking is one of the most common injuries from children's toys. Some of the common objects cause choking are: balloons, coins, safety pins, small office supplies (paperclips, tacks, etc.), marbles, small balls, nails, bolts, screws, erasers, batteries, broken crayons, and jewelry (rings, earrings, pins, etc.) Since a Brachistochrone device uses small projectiles, choking will be a concern. There may be a reason to either prevent the children from handling the rolling projectile or making the projectile large enough to not be a choking concern. Another common choking concern is broken pieces of toys or the devices

Formatted: Font: Bold, Font color: Auto

Formatted: Normal

Commented [CTF15]: Section 2.8 created by Daniel

Formatted: Heading 3, Space Before: 2 pt

that can cause choking. So the device will have to be strong and built durable to ensure no pieces break off.Choking is one of the most common injuries from children's toys. Some of the common objects that

The child safety concerns are primarily choking. Choking is one of the most common injuries from children's toys. some of the common objects that cause choking are balloons, coins, safety pins, small office supplies (paperclips, tacks, etc.), marbles and small balls, nails, bolts, and screws, erasers, batteries, broken crayons, jewelry (rings, earrings, pins, etc.) Since a Brachistochrone device uses a type of projectile choking will be a concern. There may be a reason to either prevent the children from handling the rolling projectile or making the projectile large enough to not be a choking concern. Another common choking concern is broken pieces of toys or the devices that can cause choking. So the device will have to be strong and built durable to ensure no pieces break off.

Figure 2-12: Choking hazards, American Academy of Pediatrics

2.15.2 Cuts and Lacerations

During construction nails and screws should be noted for potential injury risk. Since children are unpredictable, every surface of the Brachistochrone will need to be free of any sharp edges. If wood is used, it should be sanded and smoothed to ensure no splinters are caused. Broken pieces can also lead to sharp edges so durability will help in preventing cuts. Tests could be done on the Brachistochrone to ensure durability before it is placed inside the museum.

2.15.3 Tipping of the Structure

Depending on the size of the device, children could attempt to climb onto the structure, causing it to tip and fall. A falling structure could cause injury to multiple people, so stability and durability will be important. A wide base or a heavy structure may help in stability so that no one is hurt by a falling object. Guide Rails can also prevent children from climbing on top. Although stability is a major factor in prevention of tipping, prevention is also a very good method. By making the structure hard to climb, or it's too small to climb all together can eliminate the risk of injury from tipping.

Formatted: Caption

Commented [c16]: Need to come back and add web address

Formatted: Heading 3, Space Before: 2 pt

Formatted: Heading 3, Space Before: 2 pt

2.15.4 Magnets

Recently magnets in children's toys has become of concern. rare earth magnets can be a great tool due to their strong magnetic attraction. However, since they are small in size and fall out of housings easily, they are ingested by accident by small children. This can lead to gastrointestinal damage if two magnets stick together in the bowls or the child. Magnets could very well be in the Brachistochrone device. This means that extra caution should be taken when, where and what is holding the magnet. If any magnets are being used it will be very important to make sure they do not fall out and become accessible to children.

2.16 Child development ~~– motors skills of different age groups, what height can they reach.~~

Commented [CTF17]: Section 2.9 created by William

Formatted: Heading 3, Space Before: 2 pt

2.16.1 Motor skills of different age groups

The targeted age group for this design project is from the ages 3 to 8. Motor skills alter with each increasing age so it's important to know which each of them are capable of. When toddlers are between the ages of 3 to 4, they are able to have control of both feet when moving and even turn door knobs. This is good because if our design does need the children to walk up a foot stool to release the balls then our lowest targeted age is capable of doing it. Ages 5-6 kids are more aware of their motor skills and can run, climb, jump. They can throw and kick balls, so being able to start the project will be no problem. Ages 7-8 the kids are more than capable of being able to reach the top of the table with or without a stepping stool. They will also be able to start and reset the machine with no difficulties.

~~2.18.1~~2.16.2 Attention Span

Attention span is important to our project because we want something that will engage the children and not bore them. So it is important to know that children between the ages of 3 and 8 have different attentions spans. As they grow older their attention spans increase as well. ~~The figure~~

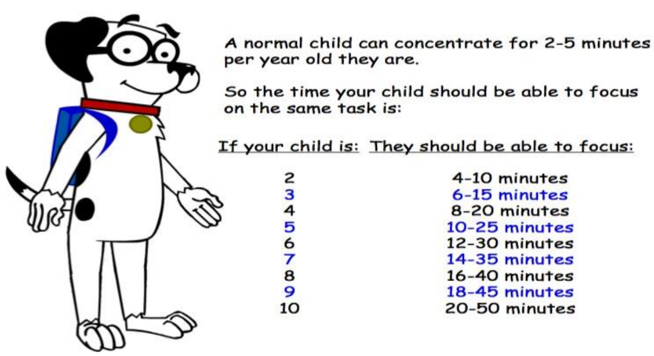


Figure 2-13: Shows the attention span from children ages 2 to 10 (Hill 2015).

~~2.18.2~~2.16.3 Child Appeal

~~2.19~~ Children like bright colors like red and green and blue. They are also more interested when they something to interact with so they don't get bored. This benefits our design project because we will have different colored Hot Wheel cars which will also invite competition. Having competition will make the kids want to play more than once depending on their age.

2.17 Client criteria

Commented [CTF18]: Section 2.10 created by William

2.17.1 Sturdiness

Formatted: Heading 3, Space Before: 2 pt

One of the main emphasis that the client put on the project was that it had to be sturdy, have longevity. The sturdiest material that would be cheap and efficient would be carving tracks out of wood. Metal tracks would be efficient but being able to carve the tracks would be difficult.

2.17.2 No Screens

Formatted: Heading 3, Space Before: 2 pt

The client also made it clear that electricity could be used but wanted to stay clear of any kind of digital screen such as a computer or television screen. The targeted age group of 3-8 are kids born in a generation of screens. They all are growing up with cell phones and IPADS, so being able to enlighten and engage them is a priority for building this project.

3 Alternative Solutions

3.1 Introduction

The Alternative Solutions section includes plausible design solutions for the Brachistochrone, incorporating the brainstorming process that lead to the different designs, as well as adhering to the client specified criteria. The brainstorming process is detailed below in section 3.2, and the top design ideas are explained in below in section 3.3.

3.2 Brainstorming Process

Team Schmotron utilized the brainstorming process to generate ample ideas for all aspects of the BrachistocroneBrachistochrone. The process included both structured and unstructured brainstorming techniques. See Appendix B and Appendix C for brainstorming notes. The first unstructured technique consisted of constantly bouncing any ideas we had individually off of each other and improving upon them for the first several weeks of the project. The second unstructured technique included a timed brainstorming session where we simply thought about any alternative solutions for any part of the project with no restraints. The list was recorded with pencil and paper and then re-evaluated by the group. Topics were crossed off if they did not seem practical or violated any constraints. Any ideas that were liked among the group were circles to evaluate further later. Several ideas were able to be combined with other ideas. The unstructured session was followed by a timed structured session where the topic was 'mechanisms' implying any modifications beyond a simple track. This includes simultaneous starting mechanisms, finish line placement mechanisms, and interesting track modifications or additions. AgainAgain, we analyzed our results and crossed off, circled, or combined using the same method as before. Our pen and pencil brainstorming notes can be found in the Appendix.

3.3 Alternative Solutions

3.3.1 Simple ~~3~~ Three Track Brachistochrone

The Simple ~~3~~ Three Track Brachistochrone lays down a basic foundation to meet the client's minimum criteria. The base is constructed of wood. A wooden skeleton support is cut from a plywood sheet to match each curve. A flat track of bendable wood is then affixed to the skeleton. A lane of Hot Wheels track is then affixed to the wooden tracks for each of the 3 curves. It contains 3 tracks of different style curves. The track located at point **C** in Figure 3-1 is a straight line. The track located at point **D** in Figure 3-1 begins with a steep slope and continues with a near horizontal line. The track located at point **F** in Figure 3-1 is a cycloidal curve. The starting point located at point **A** in Figure 3-1 has no simultaneous starting mechanism, children simply place their car on the track at point **A** and release their car by hand. The end located at point **B** in Figure 3-1 is constructed from wood with a slim rubber padding, it is there to stop the cars when they reach the end of the track.

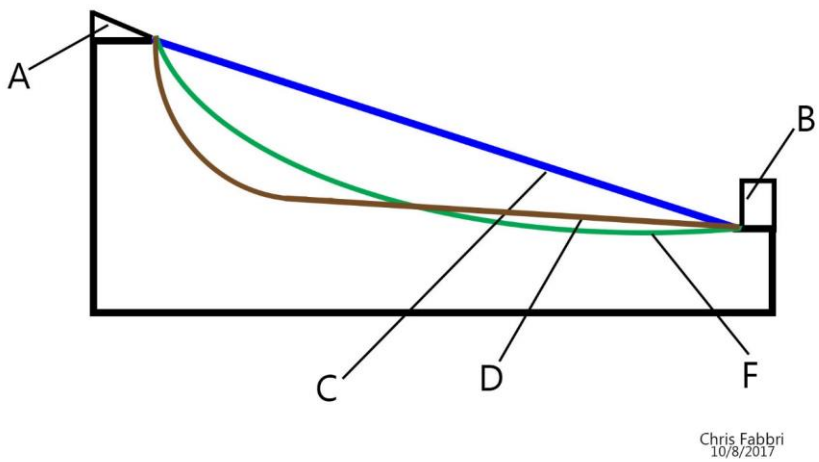


Figure 3-1~~3-1~~: Simple ~~3~~ Three Track Brachistochrone

3.3.2 Simple ~~4~~ Four Track Brachistochrone

The Simple ~~4~~ Four Track Brachistochrone mimics the Simple 3 Track Brachistochrone laid forth in section 3.3.1 with the addition of an extra 4th track. The base is constructed of wood. A wooden skeleton support is cut from a plywood sheet to match each curve. A flat track of bendable wood is then affixed to the skeleton. A lane of Hot Wheels track is then affixed to the wooden tracks for each of the 4 curves. It contains 4 tracks of different style curves. The track located at point **C** in Figure 3-2~~Figure 3-1~~ is a
The track located at point **D** in Figure 3-2~~Figure 3-1~~ begins with a steep slope and continues with a near line. The track located at point **E** in Figure 3-2 is a portion of a circle. The track located at point **F** in Figure 3-2~~Figure 3-1~~ is a cycloidal curve. The starting point located at point **A** in Figure 3-2~~Figure 3-1~~ has starting mechanism, children simply place their car on the track at point **A** and release their car by hand. The end located at point **B** in Figure 3-2~~Figure 3-1~~ is constructed from wood with a slim rubber padding, to stop the cars when they reach the end of the track.

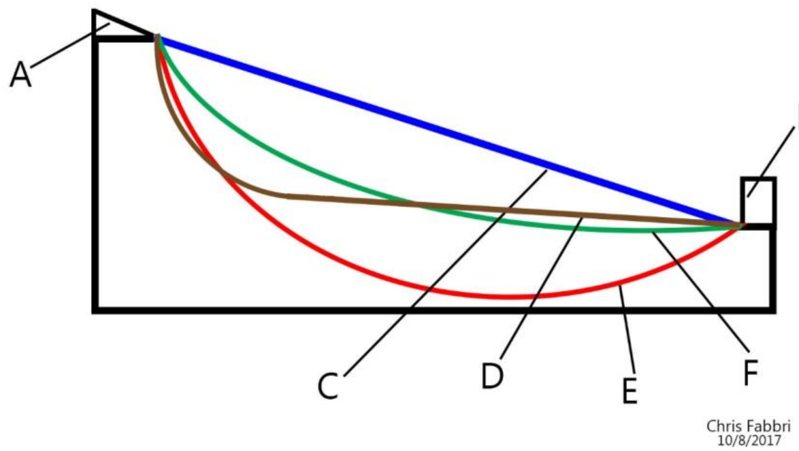


Figure 3-23-2: Simple 4Four Track Brachistochrone

3.3.3 4Four Track Brachistochrone with Lever Start

The 4 Four Track Brachistochrone with Lever Start is an upgraded version of the Simple 4 Four Track Brachistochrone from section 3.3.2 with the addition of a simultaneous lever start mechanism. The base is constructed of wood. A wooden skeleton support is cut from a plywood sheet to match each curve. A flat track of bendable wood is then affixed to the skeleton. A lane of Hot Wheels track is then affixed to the wooden tracks for each of the 4 curves. It contains 4 tracks of different style curves. The track located at point **C** in Figure 3-3 is a straight line. The track located at point **D** in Figure 3-3 begins with a steep slope and continues with a near horizontal line. The track located at point **E** in Figure 3-3 is a portion of a circle. The track located at point **F** in Figure 3-3 is a cycloidal curve. The starting point located at point **A** in Figure 3-3 has been equipped with a simultaneous starting mechanism consisting of a lever arm. The lever arm is attached at point **G** with a hinge that enables it to rotate. The lever arm comes down at point **I** to block all 4 tracks. When a child pulls the lever at point **H** it causes the portion of the lever arm at point **I** to raise, releasing all 4 cars simultaneously. The end located at point **B** in Figure 3-3 is constructed from wood with a slim rubber padding, it is there to stop the cars when they reach the end of the track.

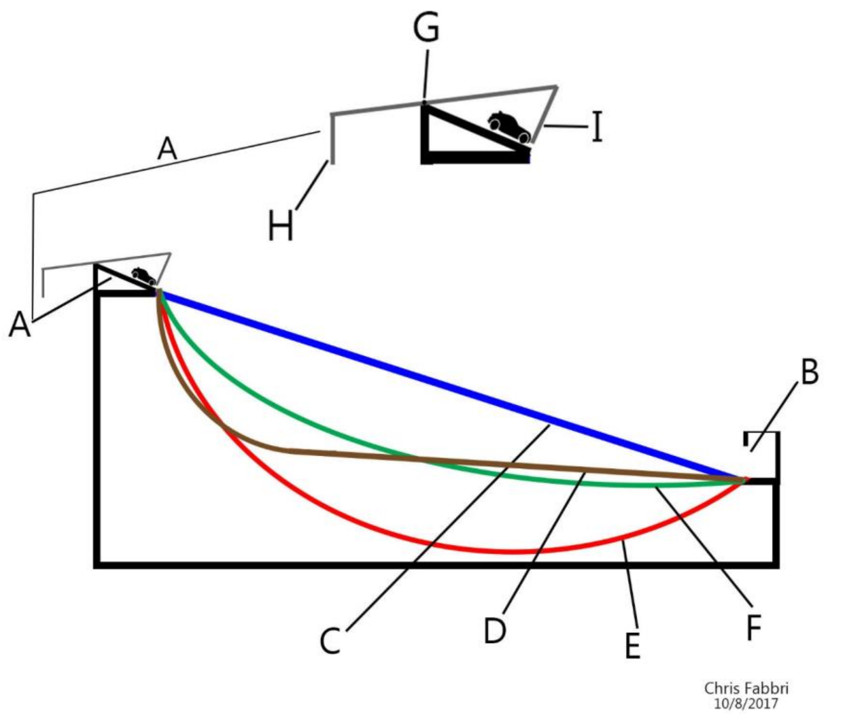


Figure 3-~~3~~3~~-3~~: ~~4~~ Four Track Brachistochrone with Lever Start

3.3.4 ~~4~~ Four Track Brachistochrone with Lever Start and Infrared Finish

The ~~4~~ Four Track Brachistochrone with Lever Start and Infrared Finish in Figure 3-4 is an upgraded of the ~~4~~ Four Track Brachistochrone with Lever Start from section 3.3.3 with the addition of an infrared finish line placement mechanism. The base is constructed of wood. A wooden skeleton support is cut from a plywood sheet to match each curve. A flat track of bendable wood is then affixed to the skeleton. A lane of Hot Wheels track is then affixed to the wooden tracks for each of the 4 curves. It contains 4 tracks of different style curves. The track located at point **C** in Figure 3-4 is a straight line. The track located at point **D** in Figure 3-4 begins with a steep slope and continues with a near horizontal line. The track located at point **E** in Figure 3-4 is a portion of a circle. The track located at point **F** in Figure 3-4 is a cycloidal curve. The starting point located at point **A** in Figure 3-4 has been equipped with a simultaneous starting mechanism consisting of a lever arm. The lever arm is attached at point **G** with a hinge that enables it to rotate. The lever arm comes down at point **I** to block all 4 tracks. When a child pulls the lever at point **H** it causes the portion of the lever arm at point **I** to rise, releasing all 4 cars simultaneously. The end located at point **B** in Figure 3-4 is constructed from wood with 4 break beam infrared sensors sunk into the wood located at point **K**. Point **J** shows the break beam infrared beams. The infrared sensors are connected to an Arduino module hidden from view that has been programmed to detect when a car has crossed the break beam. Once a car has been detected the Arduino module will be programmed to turn on one of 4 different colored lights, located at point **L**, corresponding to which track had the car that finished first. There is a reset button located at point **M** near the lights to reset the system and turn off the lights in order for a new race to be conducted.

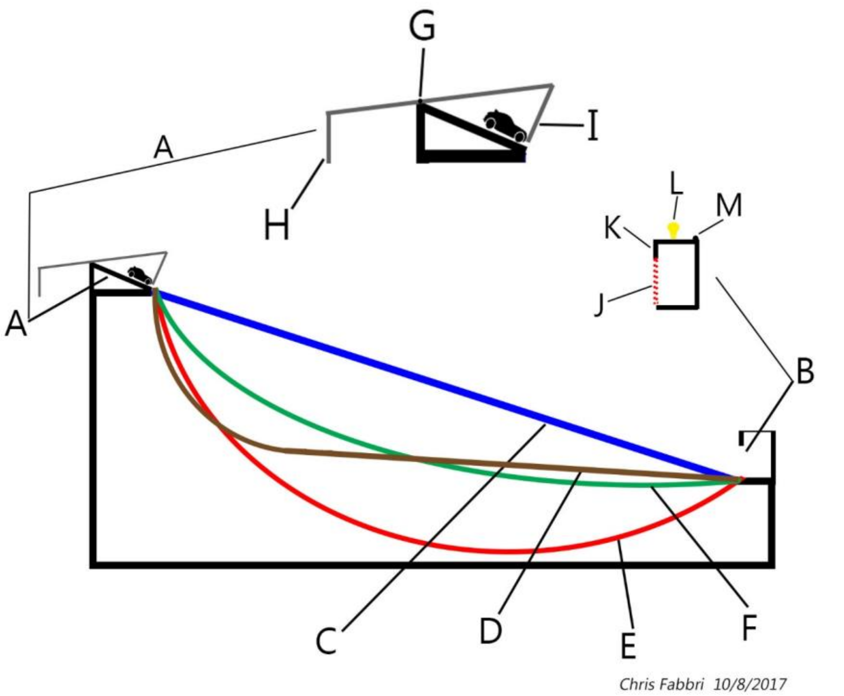


Figure 3-43-4: ~~4~~ Four Track Brachistochrone with Lever Start and Infrared Finish

3.3.5 ~~4~~ Four Track Brachistochrone with Lever Start and Improved Infrared Finish

The ~~4~~ Four Track Brachistochrone with Lever Start and Improved Infrared Finish in Figure 3-5 is an upgraded version of the ~~4~~ Four Track Brachistochrone with Lever Start and Infrared Finish from section 3.3.4 with the addition of 4 digital displays instead of light bulbs. The base is constructed of wood. A wooden skeleton support is cut from a plywood sheet to match each curve. A flat track of bendable wood is then affixed to the skeleton. A lane of Hot Wheels track is then affixed to the wooden tracks for each of the 4 curves. It contains 4 tracks of different style curves. The track located at point **C** in Figure 3-5 is a straight line. The track located at point **D** in Figure 3-5 begins with a steep slope and continues with a near horizontal line. The track located at point **E** in Figure 3-5 is a portion of a circle. The track located at point **F** in Figure 3-5 is a cycloidal curve. The starting point located at point **A** in Figure 3-5 has been equipped with a simultaneous starting mechanism consisting of a lever arm. The lever arm is attached at point **G** with a hinge that enables it to rotate. The lever arm comes down at point **I** to block all 4 tracks. When a child pulls the lever at point **H** it causes the portion of the lever arm at point **I** to rise, releasing all 4 cars simultaneously. The end located at point **B** in Figure 3-5 is constructed from wood with 4 break beam infrared receivers sunk into the wood located at point **K**. 4 infrared transmitters are placed in the wood at the bottom of the infrared beams located at Point **J**. The infrared sensors are connected to an Arduino module located at point **P** hidden from view contained in a wooden box, it is accessible via a keyed access panel on the side of the box. The Arduino has been programmed to detect when a car has crossed the break beam. Once a car has been detected the Arduino module will be programmed to turn on the 4 digital displays, located at point **O**, which show "1st, 2nd, 3rd, or 4th". There is a reset button located at point **M** near the displays to reset the system and turn off the displays in order for a new race to be conducted. All sensors and wiring is hidden from view.

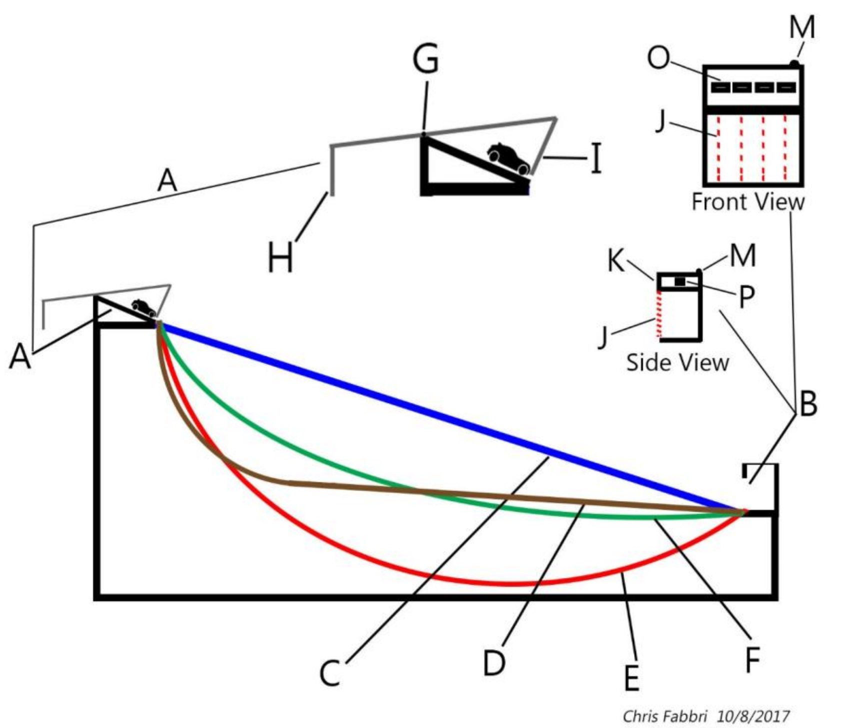


Figure 3-53-5: 4 Four Track Brachistochrone with Lever Start and Improved Infrared Finish

An alternative possible future add on feature to this design is the ability to track the time it takes each car to travel down each curve. This is a simple addition that requires a closed circuit wired at the start gate located at point **I**. When the gate is raised the circuit breaks signaling the Arduino to start the timer. When each car crosses the break beam the time is stored and then displayed on the display screen, alternating every 3 seconds between their place (1st, 2nd, 3rd, or 4th) and their time. The Arduino's code will need to be updated for this feature.

3.3.6 ~~4~~ Four Track ~~Brachistichrone~~Brachistochrone with Pop-Up Flag Ending Mechanism

The ~~4~~ Four track ~~Brachistichrone~~Brachistochrone with a pop-up flag ending mechanism is an alternate solution to determine which ball finishes the track first. It follows the basic layout as seen in Figure 3-2 of the 4 track ~~Brachistichrone~~Brachistochrone but has an alternate ending. This is shown in detail in ball rolls down the track it hits a cylindrical pocket at point A. This pocket is attached to an axel underneath located at point D. The balls forward momentum hits the pocket and causes the axel to spin. The axel is also connected to a flag at point C, where it lies flush with the track until the axel is turned. The first flag to pop up signals which ball hit the end line first.

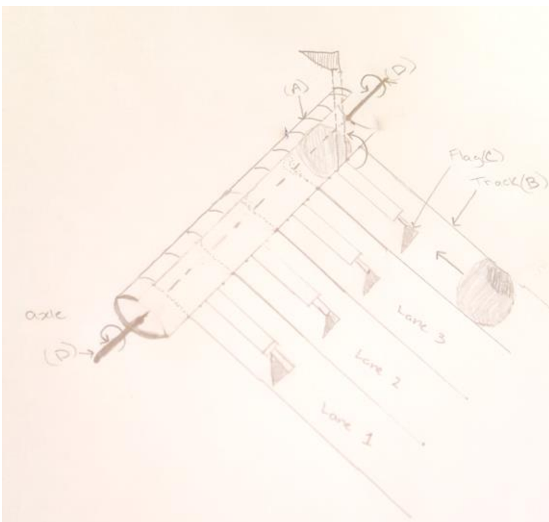


Figure 3-6~~3-6~~: Pop Up Flag Ending Mechanism – Created by William Nitzsche

3.3.7 ~~4~~ Four Track ~~Brachistichrone~~Brachistochrone with pull string starting mechanism

The ~~4~~ Four track ~~Brachistichrone~~Brachistochrone with a pull string starting mechanism is an alternate solution to how the balls are all released simultaneously at the beginning of the track. A detailed drawing is seen in Figure 3-7. The balls all start in an inclined position behind a barrier at point E. The barrier, seen at point D, is attached to an axel that stretches the entire width of track and lies underneath the ramp. The very end of the axel, located at point C, has a piece of string attached to it so that when it is pulled it rotates in a clockwise motion, causing the barrier to rotate out of the balls way. This string is pulled through a hook located at point B, and hangs down with a weighted handle. This handle at point A should be long enough so that a child can pull it with ease.

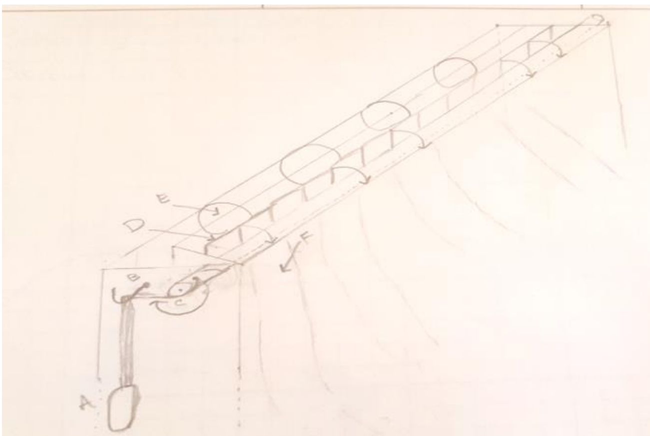


Figure 3-~~7~~7~~3-7~~: Draw String Ending Mechanism- Created by William Nitzsche

3.3.8 ~~4~~ Four Track ~~brachistrochrone~~Brachistochrone "Hot-Balls"

The ~~4~~ Four ~~T~~track ~~brachistrochrone~~Brachistochrone "Hot Balls" can be paired with any start mechanism and any end mechanism. The main layout for this alternative is the same as ~~all the other previous ones~~the previously described design in Figure 3-2, except with a different track design. This track design specifically made to be able to accommodate the use of balls on the track, or the use of cars on the track. As seen in Figure 3-8, this track consists of the use of two symmetrical and identical piece of track (C) joined together to create a gap (D). This gap is set just far enough to where a ball (B) can roll down the Gap, but just big enough to where a car (A) can't fall through. Thus, a track perfect for hot wheels or balls.

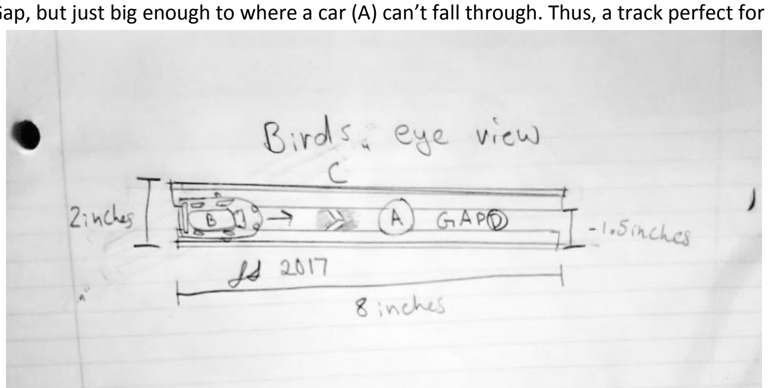


Figure 3-~~8~~8~~3-8~~ "Hot-Balls" Created by Juan Sanchez

3.3.9 ~~4~~ Four Track ~~brachistrochrone~~Brachistochrone "Double Pleasure to My Ears"

This alternative solution is like 3.3.8 but with a wild twist. Just like the previous alternative this tack model can run both cars and balls on its track, but unlike its earlier alternative, it can run them both at the same time. This track instead of using less material and creating a gap in the track, using more material and erects a wall on either side of the track providing enough clearance for a car to travel under the protection of the walls as shown in Figure 3-9. This allows there to be a ball (B) rolling on top of each individual track (C) while a car (A) is riding in between the walls of the track. With the ability of having two different projectiles rolling down the track at the same time it causes many of the previous stated end placement mechanism to be ineffective in this specific design resulting in a new end design as well. This mechanism is also displayed as D and F in Figure 3-9. It consists of applying similar tube design as a xylophone in a way that as the ball and car strike their individual ends, it will create a specific sound to that specific track.

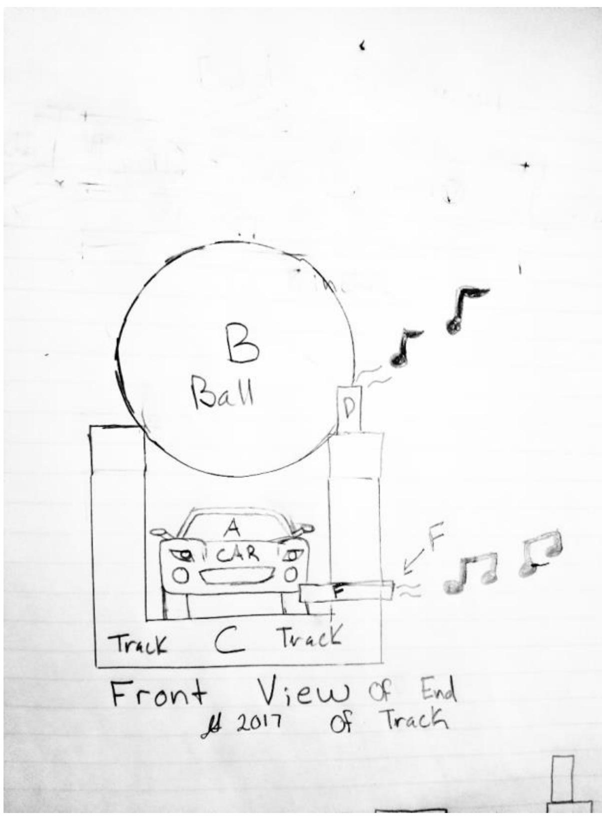


Figure 3-9~~3-9~~ Double Pleasure to My Ears – Created by Juan Sanchez

3.3.10 Pin drop Start Mechanism

Another possible start mechanism could be a mechanical pin drop. This allows there to be no possible human error in the drop of the objects in the ~~brachistrochrone~~Brachistochrone. A variation of an already designed pin drop mechanism made and testes by Oocities could be customized and implemented into the ~~brachistrochrone~~Brachistochrone. Figure 3-10 demonstrates how Oocities demonstrates their image below. The part labeled a as well as track is flush with the pin once the part labeled c is triggered. Once the part label C is triggered then part B , a spring assisted hinge snaps closed pulling the pin with it and releasing the cars. This start Mechanism can be used with any finish and track except with the track from section Figure 3-9.

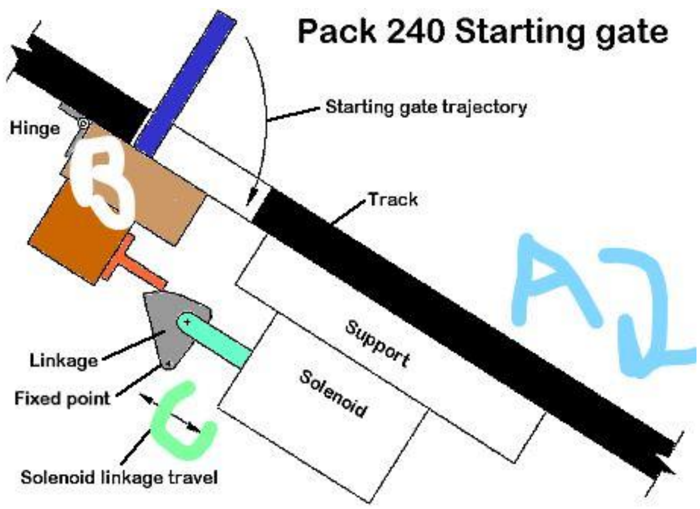


Figure 3-10~~3-10~~ http://www.oocities.org/heartland/plains/8340/start.htm

3.3.11 Spring Loaded Door Start Mechanism

A spring from a mouse trap can be used to assemble a spring loaded door. In order for the Brachistochrone to function within the constraints, gravity must me the only force accelerating the projectiles. If a door could open upwards, the balls can fall due to gravity alone. By looking at the diagram in figure 10, the spring from a mouse trap is shown at point A to be attched to the back of the device. The mechanism works similarly to a mouse trap, without the killing power of course. A latch can be placed at point B in order to keep the door closed. The latch can be relesed by pressing a button, causing the door to open and the projectiles to be exposed as we see in point C. At this point the race will begin towards the finish. Another latch can be positioned in the back to catch the door as it opens so the door does not bounce back to the origin. A spring loaded door will becost effective and easy to assemble.

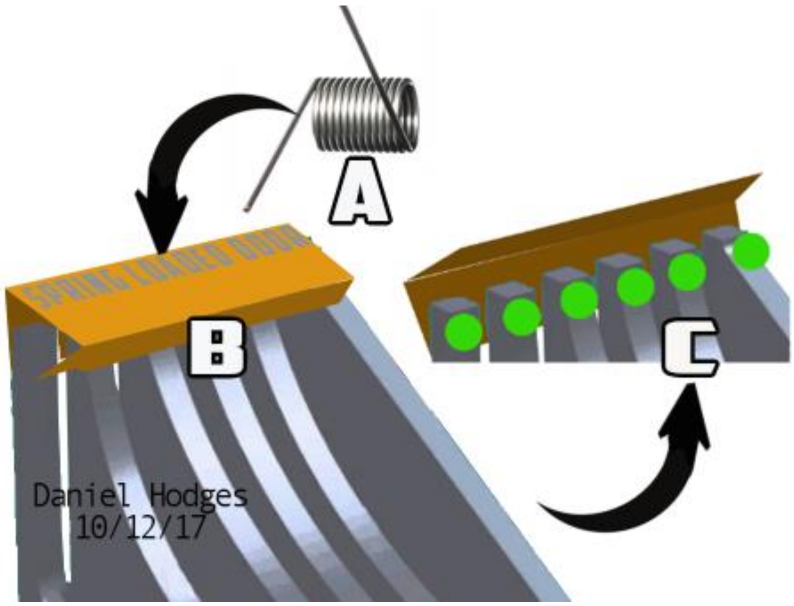


Figure 3-3-113-11: Spring Release Door – Created by Daniel Hodges

4 Decision

4.1 Introduction

4.1 Section 4 explains and justifies the process that was used when choosing the final design of the This section will go into detail about how the criteria, specifications, and alternate solutions from Section 3, and how they affect the outcome of the final process. The following sub-sections include the details of the criteria, how we went about analyzing the alternate solutions with a Delphi Matrix chart as well as the final design and decision process of this project

Section 4 is incorporated to explain and justify the process that takes place when choosing the final design of the project. This section will go into detail about how the criteria, the specifications, and how the alternate solutions from section 3 affect the outcome of the final process. The following sub-sections include the details of the criteria, how we went about analyzing the alternate solutions with a Delphi Matrix chart, see Figure 4-1 in section 4.4, as well as the final design and decision process of this project.

4.2 Our criteria are primarily designed to ensure durability and longevity of the Brachistochrone. concerns that rate highest between the client and our team is weight, size, and the number of tracks. The criteria are listed and explained below. The Brachistochrone could be a long-lasting exhibit if these criteria are incorporated into the final product.

Our criteria are primarily designed to ensure durability and longevity of the Brachistochrone. The

The criterion for the safety of the final product is a combination of sturdiness and choking client's main concern with all of their exhibits, current and future, is the safety of children. The exhibit needs to be sturdy enough to where a child can't move it or cause it topple over. But not to heavy where it interferes with the movability criteria. The exhibit also needs to be free of choking hazards. This is why the design uses golf balls and hot wheel cars, because they are all above the choking size diameter. This is why our client weighted this criterion at a ten.

4.2.1 The criterion for the physical weight of the final product is a combination of the need of safety

The criterion for the overall size is comprised of mobility and accessibility. The client thinks that sized design is better with the idea of increasing the time a vehicle slides down the Brachistochrone track, which in turn will also increase the excitement and appeal of the exhibit. Keeping the movability of the exhibit practical is also important when considering size, thus the constraint that it must be able to fit through an average door frame. The overall size must be able to be carried by at least two people. This is very important to them with a weight of ten.

Our client made it clear that projects and exhibits should excite children and adults alike in a

The criteria based on cost was very easy for the client to come by, they expect us to use more to better ensure quality but limited by the maximum amount of funding- available, which is $500. If total cost lands somewhere in this range then it will be acceptable, thus the importance weighted to 6 out of 10.

This criteria was very easy for the client to come by, the would ideally expect us to use more than $150 to better ensure that the product isn't created too "cheaply" but limited us to the maximum amount of funding available, which is $500. As long as total cost lands somewhere in this range than it will be acceptable, thus the importance weighted to 6 out of 10.

The client specified that they would love instructions on how to build another similar based on this project. This consideration is due to the fact- that they couldn't find one anywhere in Humboldt. They just want to make sure that the instructions include more user -friendly instructions than those given by IKEA's products, giving this criteriathis criterion a weight of 6 out of 10.

The client specified that they would love instructions on how to build another similar Brachistochrone based on this project. This is due to the consideration that they couldn't find one anywhere in Humboldt. They just want to make sure that the instructions include more user friendly instructions than those given by IKEA's products. This too received a weight of 6 out of ten.

One of the more important aspects of our product to the client. Simply stated by them that is 3 or more tracks, with no upper bound.

This one of the more important aspects of our product to the client. Simply stated by them that is must have 3 or more tracks, with no upper bound.

The structural aesthetics of our project were just constrained at "it just can't look like it was together or too homemade" with the importance of the criteria being a 5 out of 10.

~~The structural aesthetics of our project were just constrained at "it just can't look like it was slopped~~

With the spirit and green ideals of HSU and the Redwood Discovery Museum, our group and the came up with the criteria that the project would consist of at the least ten percent up-cycled materials. There is no upper bound and the more up-cycled materials used the better. With this not being their top priority, they weighted it at 5 out of 10.

~~With the spirit and green ideals of HSU and the Redwood Discovery Museum, our group and the client came up with the criteria that the project would consist of at the least ten percent up-cycled materials. There is no upper bound and the more up-cycled materials used the better. With this not being their top priority, they weighted it at 5 out of 10.~~

The most practical solutions were compiled~~s~~ from section 3 for further analysis. The chosen solutions include:

- 4 Track Brachistochrone with Lever Start and Improved Infrared Finish
- 4 Track Brachistochrone with Pop-up Flag Ending Mechanism
- 4 Track Brachistochrone with Pull String Starting Mechanism
- 4 Track Brachistochrone "Hot-Balls"
- 4 Track Brachistochrone "Double Pleasure ~~To~~to My Ears"
- Pin Drop Start Mechanism
- Spring Loaded Door Start Mechanism

4.4 Decision Process

This decision process evaluated the alternative solutions from section 4.3 and judged them based on the criteria from Section 2. Each criterion is given a weighted number 0-10, where 10 is the most valued weight and 0 is the least valued. The alternative solutions, are scored from 0-50. Weighted criteria are inserted in a Delphi matrix, where the products of these two are summed up and listed as their final scores. These totals are used to make the final decision, along with team discussion and client input. The Delphi Matrix can be viewed below in Table 2~~Figure 4-1~~.

Table 2: Delphi Chart for Brachistochrone Alternative Solutions

Formatted: Normal, No bullets or numbering

Formatted: Caption, Centered, Don't keep with next

~~This decision process was done by evaluating the alternative solutions from section 4.3 and judged~~

Criteria	Weight (0-10)	Alternative Solutions: 4 Track Brachistochrone with lever start and improved Infrared Finish	4 Track Brachistochrone with Pop-Up Flag Ending Mechanism	4 Track Brachistochrone with Pull String Starting Mechanism	4 Track Brachistochrone "Hot -Balls"	4 Track Brachistochrone "Double Pleasure to My Ears"	Pin Drop Start Mechanism	Spring Loaded Door Start Mechanism
Weight of Final Product	10	35 / 350	40 / 400	45 / 450	40 / 400	40 / 400	45 / 450	40 / 400
Overall Size	10	45 / 450	35 / 350	35 / 350	20 / 200	20 / 200	30 / 300	30 / 300
Cost	6	40 / 240	31 / 186	27 / 162	30 / 180	31 / 186	28 / 168	26 / 156
Aesthetics	5	42 / 210	33 / 165	31 / 155	30 / 150	33 / 165	40 / 200	41 / 205
Up-cycled Material	5	25 / 125	25 / 125	25 / 125	25 / 125	25 / 125	25 / 125	25 / 125
Construction Instruction	6	15 / 90	38 / 228	39 / 234	40 / 240	45 / 270	35 / 210	30 / 180
# of Tracks	8	50 / 400	50 / 400	50 / 400	50 / 400	50 / 400	50 / 400	50 / 400
	Total:	1865	1854	1876	1695	1746	1853	1766

~~*Figure 4-1: Delphi Chart for Brachistochrone Alternative Solutions*~~

The justification for the final design decision was made using a combination of techniques which resulted in integrating specific components from multiple alternative solutions into a final design. The techniques used to form the decision included the following:

1) A Delphi matrix to analyze each previously created alternative solutions by creating a new criteria weight for each solution and mathematically combining the new weights with the client approved weights, resulting in a numerical scale to compare the effectiveness of each solution.

2) Thorough discussion and analysis by team members amongst each other, taking into account all known pros and cons.

3) Client input of proposed final decision, incorporating any unforeseen client needs.

The final decision combined components from several alternative solutions. Components from the top scoring mechanisms on the Delphi Chart were combined based on client feedback and team decisions. The track will consist of the hybrid "Hot-Balls" track from section 4.3.8 that enables both Hot Wheels cars or Balls to be used. The starting mechanism from section 3.10 "Pin Drop Start Mechanism" which consisted of a spring assisted pin drop is used, where the pin can drop through the gap in the track where the ball travels. The ending mechanism primarily uses the "Improved Infrared Finish" from section 4.3.5 with a redundant secondary mechanism "Music to My Ears" from section 4.3.9. This redundant end mechanism allows for precise finish line placement tracking using the Arduino chip and break beam technology, while also incorporating the xylophone mechanics providing audio recognition in addition to the digital displays. ~~The justification for the final design decision was made using a combination of techniques which resulted in integrating specific components from multiple alternative solutions into a final design. The techniques used to form the decision included the following:~~

Formatted: Outline numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 4 + Alignment: Left + Aligned at: 0" + Indent at: 0.3"

Commented [19]: Maybe re-word and id the colon necessary? What does Lonny say about colons?

Commented [20]: Maybe refer to the section that has the alternate solutions?

Commented [21]: If new section isn't created by noon tomorrow I will do that

Commented [22]: Overall great job as always, and thanks for reminding me that the chart is called a Delphi matrix

Commented [23]: Maybe re-word and id the colon necessary? What does Lonny say about colons?

5 Specification of Solution

5.1 Introduction

The purpose of Section 5 is to describe all aspects of the final design of the Brachistochrone Exhibit that is implemented at the Redwood Discovery Museum in Eureka, CA. This section describes the final solution, chosen in Section 4, which includes a detailed overview of each mechanism: Track, Vehicles, Finish Line Placement Mechanisms, and Simultaneous Starting Mechanism. This section also analyzes the total cost of the project, including monetary costs and hours invested in research, construction, and testing. Projected future maintenance costs and hours are discussed. Instructions are provided detailing how to reproduce and maintain each aspect of the Brachistochrone. And the final results are analyzed.

5.2 Description of Solution

The Brachistochrone Exhibit is a physics model demonstrating and comparing different style curves with the goal of transporting an object from a high point to a low point with only the assistance of gravity. The Brachistochrone is designed with a dual use track allowing for both cars or balls to be used as vehicles. A simultaneous starting mechanism was created to allow all 4 vehicles to be released from the top at the same time. A dual function finish line placement mechanism was devised in order to accurately track which vehicle made it to the bottom first. Each component is thoroughly detailed below.

~~(Must include detailed descriptions of your solution and at least ONE~~

The specific design for each track shown in Figure 5-1 consists of two pieces of half inch plywood that are spaced by a half inch gap in-between them, this track is then complimented with a small retaining wall. The walls purpose is to retain the projectiles on the track as they race down the centerline of the track. The specific purpose of the gap in the track is to allow the use of balls as well as cars to travel down these tracks. The total width of the functioning surface of the track is one and a half inches to reduce the chance of a projectile, such as a car, from creating too much friction if it were to bounce off the walls.

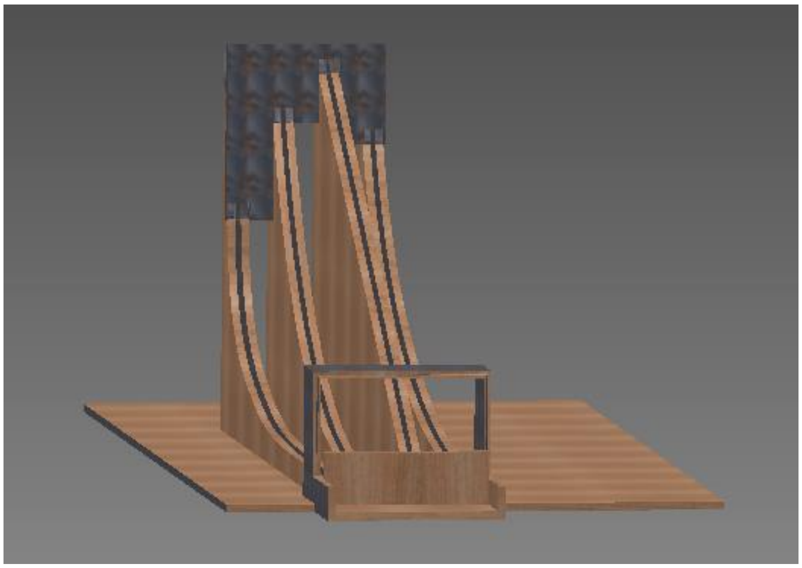


Figure 5-1: Track design by Juan Sanchez

5.2.2 Vehicles

The Brachistochrone is designed to be able to support multiple vehicle types, wheeled vehicles and spherical vehicles, see previous section 5.2.1 for track details. The primary vehicle to be used is Hot Wheels branded diecast toy cars, ~~(INSERT IMAGE LABEL FOR CARS),~~ any similarly designed diecast toy car will also work. The secondary vehicles consist of any spherical ball that ranges from 0.7”-1.7” in diameter. The main balls used during design and testing were golf balls and ping pong balls. Examples of types of vehicles can be seen in Figure 5-2. ~~(INSERT IMAGE~~

Placeholder for

Figure 5-1: Vehicle Type 1 - Hot Wheels Die Cast Toy Cars

To be able to accurately determine which track contained the vehicle which reached the finish line first, two different redundant placement mechanisms are implemented. The first mechanism is an Arduino controlled break beam photogate. The second mechanism is a Xylophone style end wall. Each mechanism is designed to invoke a different sense from the user. The Arduino controlled break beam gate is designed the users vision sense, which the Xylophone end wall is meant to stimulate auditory senses.

Figure 5-2: Possible vehicle types include cars and balls

5.2.3.1 Arduino Controlled Break Beam

In order to get an extremely accurate reading as to which vehicle finished first, an electronic circuit is needed. Based on the general design of a Pinewood Derby photogate, an Arduino controlled break beam photogate is used. The design employs infrared transmitters positioned above each track, and a matching infrared receivers positioned below each trach track in order to create an infrared beam that can be broken when a vehicle crosses, see- Figure 5-3 and Figure 5-4**INSERT IMAGE LABEL FOR PHOTOGATE PICTURE**. When the first vehicle has been detected illuminated above the corresponding track to indicate the winner. Each infrared transmitter/receiver pair, as well as the indicator LED, is wired to an Arduino microcontroller, see schematic Figure 5-5**INSERT IMAGE LABEL FOR SCHEMATIC**. The Arduino is programmed to interrupted first and then only light up that corresponding LED, in the case of a tie both LED's will light. Minimal coding is used in order to keep the cycles per second of the Arduino script as high as possible to maintain maximum accuracy. Based upon similar designs tested with an oscilloscope (**INSERT SOURCE**)by the circuits creator Ted Myers, it is expected that the Arduino every 40-50 milliseconds, providing a very accurate measurement of finish placement. The Arduino circuit used can be seen in Figure 5-5, inspiration for the circuit was gained from a 2-

lane circuit created by Ted Myers. Instructions for replicating this mechanism, replacing components, the Arduino script, and a schematic, is located in section 5.4. (INSERT SECTION

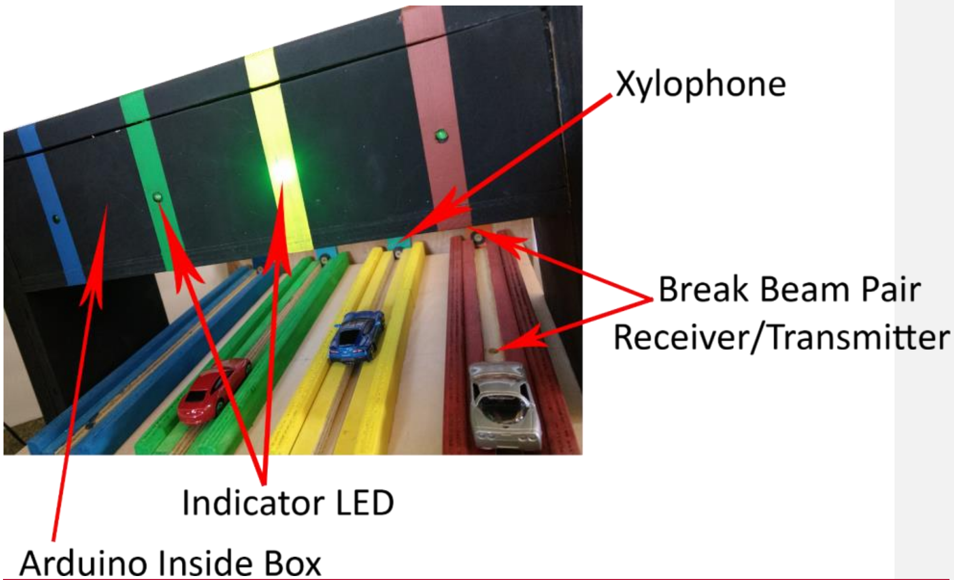


Figure 5-3: Arduino Controlled Photogate created by Chris Fabbri

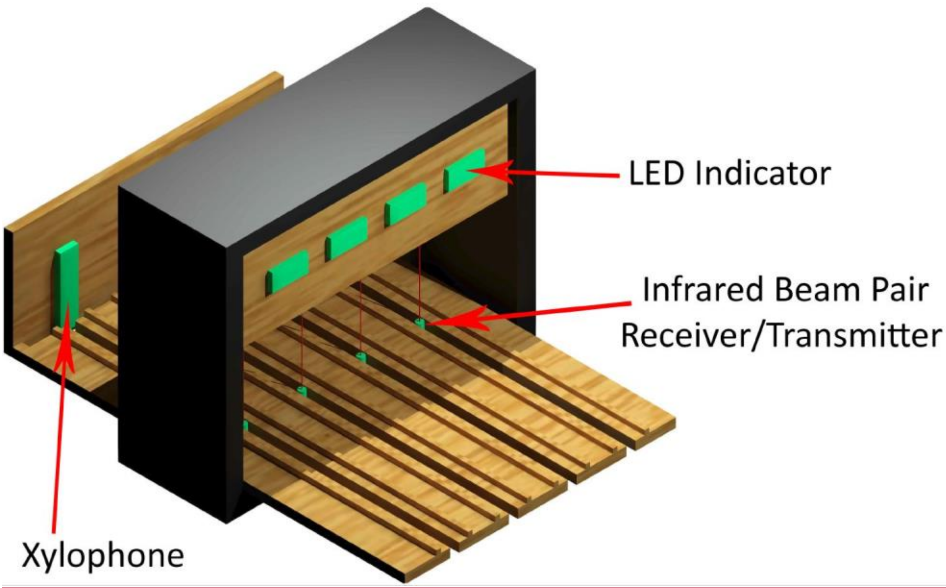


Figure 5-4:Finish Line Placement Mechanism - Created by Chris Fabbri

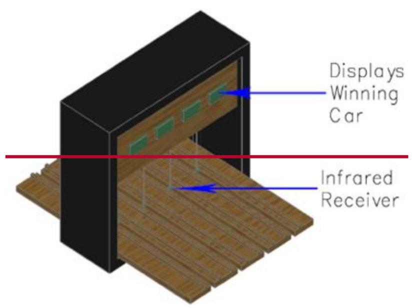


Figure 5-5: Arduino Wiring Schematic –Inspired from Similar Circuit by Ted Myers - Created by Chris Fabbri

~~*Figure 5-5: Arduino Wiring Schematic - Created by Chris Fabbri.*~~

In case of electrical failure of the Arduino controlled infrared break beam sensor, as well as to invoke auditory senses, an additional placement mechanism was implemented. The Xylophone audio recognition placement device is positioned at the end of the track. It serves a dual purpose of preventing the vehicles from falling off the end of the track, as well as indicating finish placement. The mechanism of constructed from upcycled Xylophone metal plates, affixed to a wooden back plate. Each track terminates into a different length Xylophone plate, resulting in a distinct noise for each track, see Figure 5-6~~**INSERT IMAGE LABEL FOR CAD XYLLOPHONE**~~ enable users to determine which vehicle reached the end first by listening for which noise came first.

Placeholder for

~~Picture of Xylophone~~

Ending Mechanism

Figure 5-6: Xylophone Finish Line Placement Mechanism

5.2.4 Simultaneous Starting Mechanism

In order for the balls or hot wheels to race down the track from a fixed position, a simultaneous starting mechanism had to be built. The mechanism consists of a triangular cover built of plywood ~~and Plexiglas~~. The ~~Plexiglas~~ plywood then had a square cut out of it in order to place the vehicles on the starting line. The triangular cover is then connected to the top foundation of the design by a hinge. Four individual blocks of plywood were uniquely cut out and glued to the inside of the triangular cover. These blocks are used to prevent the vehicles from rolling down the track before the starting mechanism has been activated. A handle is then connected to the cover, and when vehicles are in the ready position, and in place, the handle is pulled and the vehicles begin to race down the track.

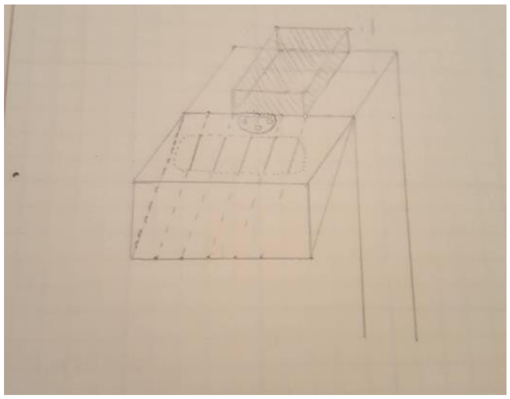


Figure 5-7: Start Gate - Created by William Nitzsche

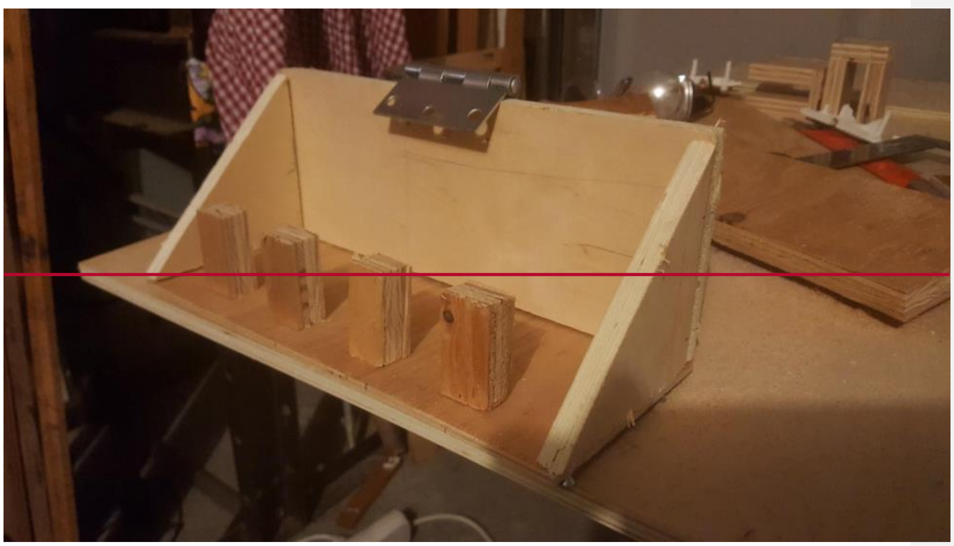


Figure 5-8: Inside blocks that prevent vehicles from rolling down track

Formatted: Indent: Left: 0.4", No bullets or numbering

5.3 Costs

~~INTRO/DESCRIPTION OF COSTS~~This section describes the costs associated with the design process for the Brachistochrone exhibit. This includes the time and monetary costs associated with the research and development as well as the construction of the final model.

5.3.1 Design Costs (Hours)

The time related design costs listed in the figure below ~~is~~ are the total time costs it took to the entire project. These costs are measured in hours. The total time it cost was 331 hours. The chart is split into 5 phases which correspond to sections 1-5 of this report.

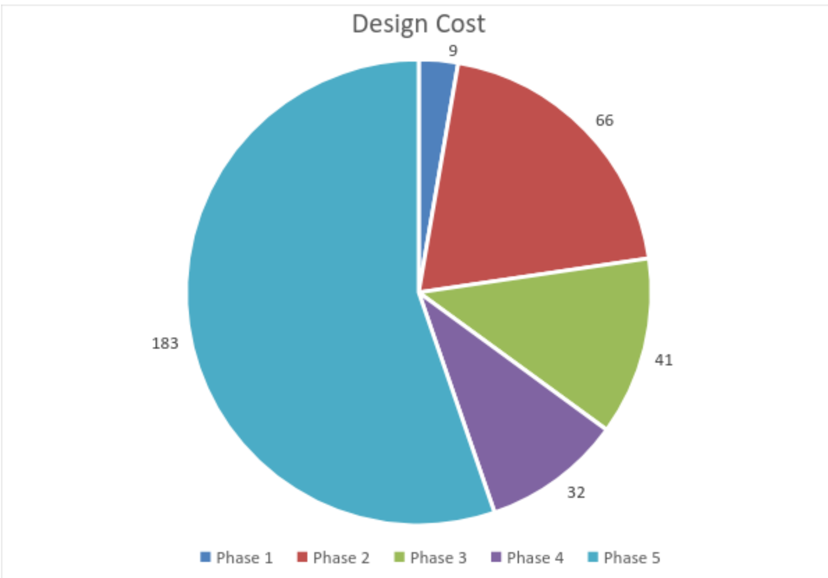


Figure 5-9: Design cost are split up between phases and how long we spent in each phase. There are a total of five phases and the total time for the design process was 331 hours.

~~ADD CHARTS OR GRAPHS SHOWING HOW MANY HOURS WENT TO WHAT PARTS~~

The implementation costs are our teams total monetary cost in how much it cost to complete the Brachistochrone curve which was described in detail in section 5.2. The table listed below shows every material used, the quantity, the projected cost and the total cost. The projected cost is there because a lot of our materials are upcycled or were donated. The total cost is listed as $337.79 new, or $208 if upcycled/donated material is used~~( )~~.

~~*Table 25-1: Material Expenses: Total inventory of materials needed and cost*~~

Material	**Quantity**	**Retail Cost**	**Our Cost**
Plywood	4 Sheets	$140.00	$108.36
Hot Wheel Cars	25	$30.00	$25.00
Scrap Wood	various	$45.00	Upcycled

Formatted: Font: Bold

Formatted: Centered

Formatted: Right

Formatted: Right

Formatted: Right

Metal Box	1	$20.00	Upcycled
Screws	50	$10.00	$10.00
Wood Glue	2	$12.00	$8.00
Sand Paper	60, 120, 220 grit	$15.00	$15.00
Hinges	2	$5.00	$5.00
Arduino Chip	1	$18.00	$17.85
Infrared Transmitter	4	$3.40	$3.40
Infrared Receiver	4	$3.40	$3.40
LED	4	$3.00	$3.00
L Brackets	3	$5.00	Upcycled
Wires	various	$10.00	Upcycled
Resistors	12	$8.99	$8.99
DC Transformer	1	$15.00	Upcycled
Total	-	**$337.79**	**$208.00**

5.3.3 Maintenance Costs

The estimated maintenance cost for upkeep on the Brachistochrone curve is listed below in Table 4, and broken down to each component that will likely need to be replaced. Each component is then broken down into how much time will be needed to replace or fix that component, as well as how much it will cost. The Arduino chip components of the finish line are rated to last many years of constant use, if however they do require replacement the price will range depending on the component. The Arduino UNO Microcontroller can be found for $12, the LED and Photoresistors tend to be $0.25 each. Repainting the design will all depend on how much damage the exterior takes from the kids playing with the design. If the damage is ~~noticeable~~ minor then painting over will only take a few minutes, costing around $5. T~~but t~~o repaint the whole design will take longer ~~up to an hour and only cost around $20.00~~. The hinge that is attached to the starting mechanism may have to be replaced depending on the amount of use it gets. Kids could pull the handle to hard and over time may become loose and need replacing. This is a simple replacement, and will only take about 5 minutes with a drill and cost around $5.00. Cleaning may need to be done depending on how much debris gets on the tracks, making it difficult for the

Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Right
Formatted: Font: Bold
Formatted: Right

vehicles to go down the track. A quick sweep or dusting will suffice and only take about 5 minutes. Hot wheel cars will need to be replaced as they are lost, stolen, or broken. These can easily be ordered online for nearly a dollar per car. Golf balls depending on what kind you buy can vary in price, but the cheapest can be found online for about $0.50 each.

~~***Table 5-2: Maintenance Costs** The components, time, and cost of maintenance is listed below*~~

Table 4: Maintenance Costs The components, time, and cost of maintenance is listed below

Estimated Maintenance Costs		
Component	**Time**	**Cost**
Arduino ~~Chip Components~~UNO Chip	~~5~~ 30 minutes	$12.00~~$0.00~~
Arduino LED/Photoresistor	30 minutes	$0.25
Repaint	1 hr	$~~20~~5.00
Hinge Replacement	20 minutes	$5.00
Hot Wheel Cars – Per Car		$1.00~~/ea~~
Golf Balls – Per Ball		$0.50~~/ea~~
Cleaning	10 minutes	$0.00
Total		$~~25~~23.~~00~~ 77

5.4 Instructions for Implementation and Use

~~Needed~~ Materials ~~Items~~Needed

- ~~3~~ 4 half inch Sheets of decent grade 4'x8' ~~sheets of~~ plywood
- ~~1~~ 4 hinges
- 3 L-Brackets
- ~~Atleast 40 screws no more than 80~~Screws of various lengths ranging from ½" to 3"
- An ~~8~~16 ~~oz~~oz. bottle of wood glue
- ~~A 15"x9" piece of pixie glass~~Paint
- 1 2' piece of 2"x4"
- Arduino UNO Microcontroller
- 4 Green LED
- 4 Infrared LED
- 4 Infrared Photoresistors
- Resistors (4 220 Ω, 4 330 Ω, 4 330k Ω)
- Metal Gate Housing
- Sand Paper

In addition to these items one will need access to a computer, power tools, and a CNC Machine.

Formatted: Font: (Default) +Body (Calibri), Font color: Auto

Formatted: Indent: Left: 0.9", No bullets or

5.4.1 ~~CONSTRUCTION OF TRACK~~Construction of Track

For the construction of the tracks one will need to cut all three sheets of plywood into 6 half inch 4’x4’ sheets of plywood by cutting each of the 4’x8’ sheets of plywood in half. One will then need to use a computer equipped with designing software such as AutoCAD or Autodesk inventor. On these programs one needs to replicate the dimensions of each 4’x4’ sheet of plywood including the width. On these programs one will then sketch the desired pair of slopes similar to those of Figure 5-1 making sure that only one pair of slopes of a track is that of a cycloid. You should have a design similar to Figure 5-8. Once you have these drawn in a design program they will need to be exported as a DWG or a DXF file so that the shapes of the tracks can be cut out by a CNC machine. Once all these shapes are cut out and you have 4 pairs of identical ~~quadrilaterials~~quadrilaterals, you will want to join each of these pairs to another one with a half inch gap in-between them as shown in Figure 5-8. These four tracks will ~~be~~ then be given walls that start after the 1.5 inch space center at the centerline. All four built tracks then will be constrained to a total width of 15”. Within these bounds the tracks will be spaced evenly and then attached to the base which is another 4’x4’ sheet of plywood. Wood glue and screws will need to be used as necessary. The end product of the tracks on the base will look like that of shown in Figure 5-8.

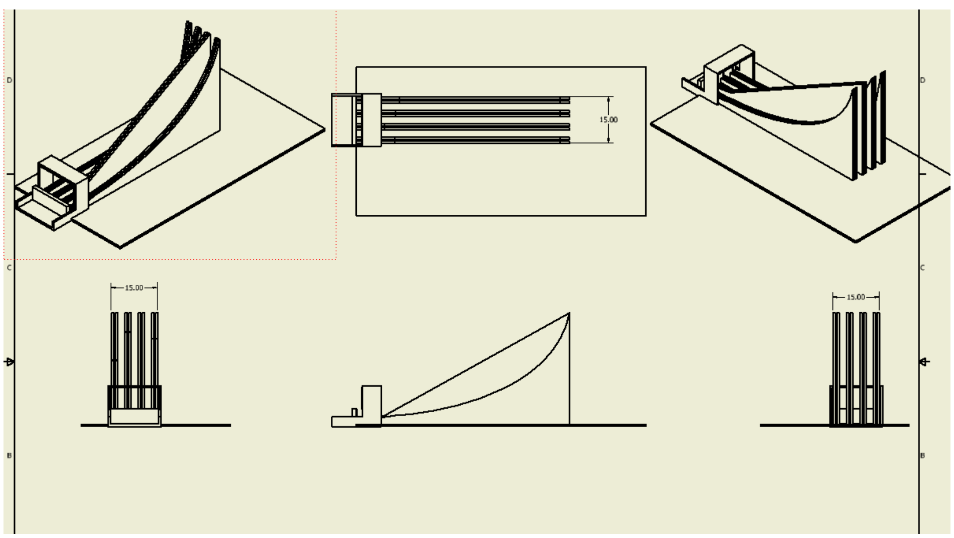


Figure 5-10: Visuals of Tracks - Created by Juan Sanchez

~~*Figure 5-8 Visiuals*~~

Figure 5-11: Dimensions for CNC Machine Cuts in Inches - Created by Juan Sanchez

5.4.2 ~~CONSTRUCTION OF FINISH~~Construction of Finish

The finish line placement mechanism is constructed from wood, with a sturdy metal housing used for the gate portion. Begin by measuring the width of the metal box to be used as the gate housing. Cut a piece of ½" plywood that spans the width of the metal box to be used as a base, and extends 6" out of the back, and 2" out of the front. Draw a line across this board directly in the center of 6" metal housing, which is 9" from the back and 5" from the front. Drill 4 holes on the center line, starting at 2.4" from the side, then space each hole 3.5" from the previous hole, see Figure 5-12~~INSERT LABEL NUMBER~~.

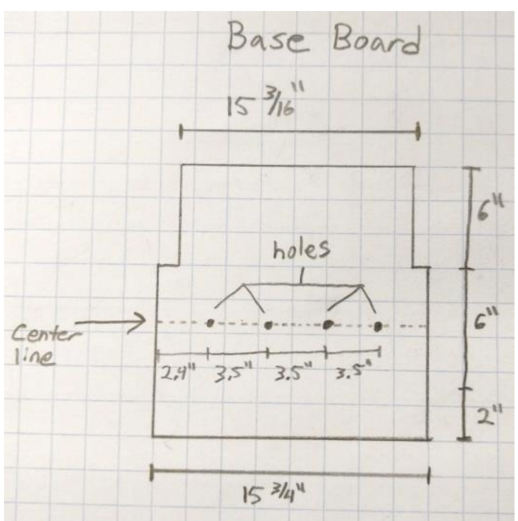


Figure 5-12: Finish Gate Base Board Dimensions– Created by Chris Fabbri

Figure 9: Finish Gate Base Board Dimensions– Created by Chris Fabbri

board. The box is to be positioned so that the infrared receiver and infrared transmitter are located within 4 inches of each other. Drill out 4 holes to mount the infrared transmitters located above the holes for the infrared receivers. Drill out 4 additional holes on the front face place of the box for the indicator LED's. Cut 8 14" long, ½" wide strips of ½" plywood to be used as track, cut 8 14" long, ¾" wide strips of ½" plywood to be used as track wall. See image- Figure the track strips so that there is a ½" gap in between, with the hole for the infrared receiver positioned in the center of the ½" gap. Glue the track wall strips on the outside of each track strip to form the dual use track.

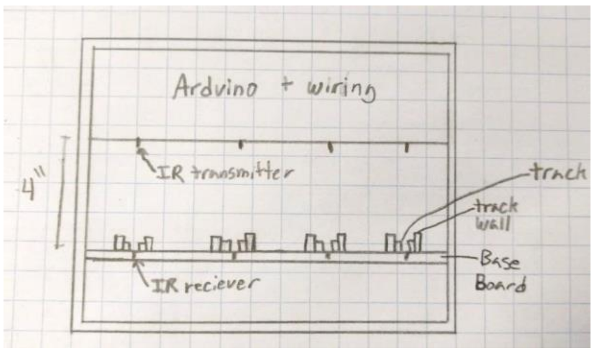


Figure 5-13: Finish Gate Front View– Created by Chris Fabbri

Wire up all the electrical components for the circuit based on the provided schematic seen in Figure 5-14. I highly recommend creating a test circuit first using a solderless bread board before creating the final circuit. Begin final circuit by soldering 330Ω resistors to the anode of each indicator LED, the anode is the short leg on the indicator LED, then solder ground wire to the other side of the resistor, and color-coded wire to each cathode. The ground wire will lead to the main ground on the Arduino and each cathode wire will lead to PIN10,11,12,13 on the Arduino. Next solder 220Ω resistors to the cathode of each IR LED, the cathode is the long leg on the IR LED, with ground wire soldered to the other side of the resistors. Solder color-coded wire to each cathode of the IR LED and run them to PIN6,7,8,9 on the Arduino. Solder four 330kΩ resistor to the positive lead wire from the 5v port on the Arduino unit, then solder the other side of each 330kΩ resistor to both the wire connected to the cathode of each IR Phototransistor and to each wire that connects to PIN2,3,4,5 on the Arduino. The cathode is the long leg on the IR Photo-transmitters. Make sure to implement a quick disconnect on the wires that travel between the lower base plate (for the IR Phototransistors) to the upper box that houses the Arduino in order to be able to separate the two halves for maintenance, also leave extra slack on these wires to make for easy connection/disconnection. Label each side of the quick disconnects in order to ensure proper reconnection. Power the Arduino with a AC to DC transformer rated between 7.5-12V 600mah-1000mah DC.

Programming the Arduino:

In order to interface and program the Arduino the “Arduino IDE” must be downloaded onto a computer. The Arduino IDE can be found at https://www.arduino.cc/en/Main/Software and is available for Windows, Mac and Linux. Download and install the Arduino IDE. After the Arduino IDE is installed, connect the Arduino UNO Microcontroller to the computer via a USB cord. Once the Arduino is connected, open up the Arduino IDE program. At the top of the program, open the drop-down menu titled “Tools” and select “Board” and then select “Arduino / Genuine UNO”. Next, from the same “Tools” drop down menu, select “Port” and the select the port that the Arduino is connected to. If there are multiple ports listed make a note of the ports, then disconnect the Arduino and see which port disappeared, then reconnect the Arduino and select that port. The Arduino is now ready to be programmed. Copy Paste the Arduino code, located after this paragraph, into the Arduino IDE program. Select the “Check Mark” at the top of the screen to verify the code. The sketch will compile and should not result in any errors, if any errors are detected, make sure that you copied the code exactly, including all of the code located between the bolded “Arduino Code Starts Here” and before the bolded “Arduino Code Ends Here” statements. Next, click on the “Right Facing Arrow” icon that is located next to the verify button, that will transfer the code to the Arduino Microcontroller. The Arduino should now be programmed. Disconnect the Arduino from the computer, verify that all wires are correctly connected to the correct pins on the Arduino as instructed by the schematic, then connect a power source to the Arduino, the circuit should now function.

The coding for the Arduino is displayed below, copy paste all of the code after the bolded “**Arduino Code Starts Here**” and before the bolded “**Arduino Code Ends Here**” statements.

Arduino Code Starts Here

```
/*
* Finish Line Detector
*
* Lights up LED 1, 2, 3, or 4 depending on which sensor is tripped first
* Both LEDs light up in the case of a tie
*
*/

const int ledPin1 = 13;
const int ledPin2 = 12;
const int ledPin3 = 11;
const int ledPin4 = 10;

const int irledPin9 = 9;
const int irledPin8 = 8;
const int irledPin7 = 7;
```

```
const int irledPin6 = 6;

const int sensorPin1 = 2;
const int sensorPin2 = 3;
const int sensorPin3 = 4;
const int sensorPin4 = 5;

// Change this number to increase or decrease time LED stays lit
const int TIMEOUT = 4000; // milliseconds - time LED stays lit

// Setup runs once, at start
// Input and Output pins are set
void setup(){
  pinMode(sensorPin1, INPUT);
  pinMode(sensorPin2, INPUT);
  pinMode(sensorPin3, INPUT);
  pinMode(sensorPin4, INPUT);
  pinMode(ledPin1, OUTPUT);
  pinMode(ledPin2, OUTPUT);
  pinMode(ledPin3, OUTPUT);
  pinMode(ledPin4, OUTPUT);
  pinMode(irledPin9, OUTPUT);
  pinMode(irledPin8, OUTPUT);
  pinMode(irledPin7, OUTPUT);
  pinMode(irledPin6, OUTPUT);
}

// Called repeatedly
void loop() {

   // Turn on IR LED
  digitalWrite(9, HIGH);
  digitalWrite(8, HIGH);
  digitalWrite(7, HIGH);
  digitalWrite(6, HIGH);

  // Get the Sensor status
  int status1 = digitalRead(sensorPin1);
  int status2 = digitalRead(sensorPin2);
  int status3 = digitalRead(sensorPin3);
  int status4 = digitalRead(sensorPin4);

  // Set the output LED to match the sensor
  digitalWrite(ledPin1, status1);
  digitalWrite(ledPin2, status2);
  digitalWrite(ledPin3, status3);
  digitalWrite(ledPin4, status4);
```

```
  if (status1 == HIGH || status2 == HIGH || status3 == HIGH || status4 == HIGH) {
    // A sensor was tripped, show the results until timeout
    delay(TIMEOUT); // Wait for timeout
  }
}
```

Arduino Code Ends Here

Wire up all the electrical components for the circuit based on the provided schematic **INSERT SCHEMATIC LABEL**. Make sure to implement a quick disconnect on the wires that travel between the lower base plate (for the IR receivers) to the upper box that houses the Arduino in order to be able to separate the two halves for maintenance. Power the Arduino with a AC to DC transformer rated between 7.5-12V 600mah-1000mah DC.

Figure 5-14: Arduino Finish Gate Wiring Schematic – Created by Chris Fabbri

For the auditory ending mechanism, Figure 11: Arduino Finish Gate Wiring Schematic – Created by Chris correspond to each track, and then attach to -the back of the base plate. See Figure 5-15.image

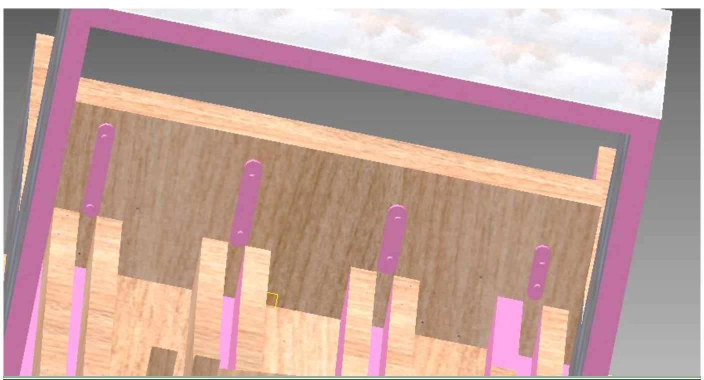


Figure 5-15: Finish Mechanism xylophone use – Created by Juan Sanchez

5.4.3 CONSTRUCTION OF STARTConstruction of Start

Starting mechanism can be constructed with a door hinge and some plywood. A hinge links the rotating door/projectile housing to the body of the brachistochroneBrachistochrone. The lever should be at least a foot in length in order to give an enough torque for an easy open.

Formatted: Centered

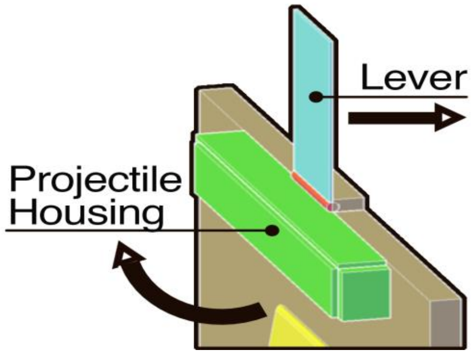


Figure 5-16: A pull on the lever will open the projectile housing. Created by DHodges.

~~Figure 7 A pull on the lever will open the projectile housing. DHodges.~~

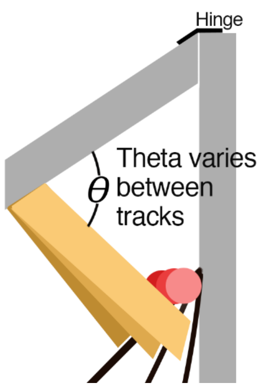


Figure 5-17:Each path is at a different angel, so each housing must be measured to keep the projectile in place - Created by Dhodges

5.4.4 ~~DESCRIBE HOW IT WILL BE USED~~Description of Use and Maintenance

The start mechanism of the ~~brachistochrone~~Brachistochrone will be used to assure that all the projectiles are being released from the same altitude at the same time. This ensures that all runs on the ~~brachistochrone~~Brachistochrone are fair and ultimately creates consistent results. To use the start mechanism the user places 1-4 vehicles (cars or balls or both) onto the tracks. The user then lifts the start gate handle to simultaneously release the vehicles. Maintenance of the start gate consists of dusting as needed and monitoring the condition of the two hinges. Hinges may need replacement after prolonged use.

The end Mechanism ~~is the use~~consists of an Arduino chip with the LED indicators as well as the use of a xylophone wall at the end to implement sound with each track to also indicate a ~~clear~~ winning ~~projectile~~vehicle. To use the ending mechanism, it simply needs to be plugged in. The

Arduino chip will power on and load the script as soon as it receives power. When a vehicle crosses the finish line the Arduino will light up the corresponding indicator LED for a set amount of time. When this time has expired the LED turned off and the Arduino resumes waiting for the next winning vehicle, there is no reset switch, it automatically resets after the set time. Maintenance consists cleaning/dusting as needed and periodically checking to confirm that all 4 tracks are being monitored correctly by simply waving your hand through the beam and confirming that the indicator LED lights up.

r time as chips in

~~DESCRIBE HOW START AND ENDING MECHISNM ARE USED~~

The results of the design prototypes led to the creation of a fully functional final design of the Brachistochrone exhibit. The final design is an educational tool capable of demonstrating the concept of the Brachistochrone path of quickest decent in an engaging, informative, and fun manner.

The initial track prototype, shown in Figure 5-18, proved to be successful for use with balls and cars and was incorporated into the final design. The heights of the walls were slightly too tall in the prototype and were scaled down in the final design to allow balls to roll down the center gap without touching the walls.

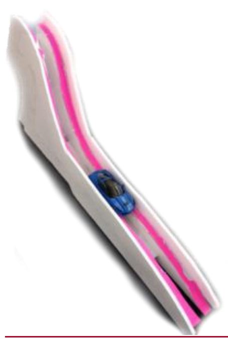


Figure 5-18: First Dual-Track Prototype - Made from ~~foamboard~~foam Board

The end gate prototype proved to be successful in accurately detecting the winning vehicle. A foamboard prototype was created to test the circuitry for the end gate as seen in Figure 5-19. Components were then placed into the foamboard prototype, shown in Figure 5-20, two tracks worth of circuitry was installed for testing. On the final design the circuitry is scaled up to four tracks and is able to reliably detect the winning vehicle, whether it be a car or a ball.

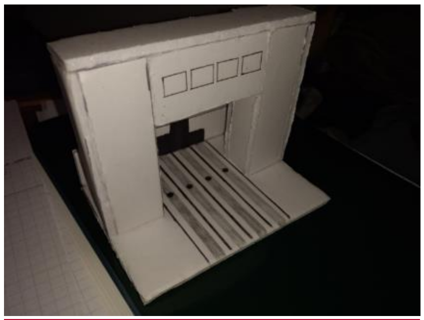


Figure 5-19: ~~Foamboard~~Foam Board Prototype of End Gate

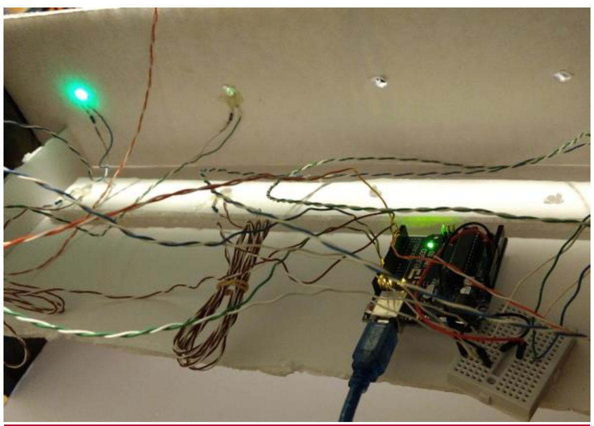


Figure 5-20: Prototype Circuitry for Two Tracks

~~DESCRIBE RESULTS OF PROTOTYPE TESTING~~

6 Appendices

~~3~~6.1 Appendix A: References

1. American Academy of Pediatrics. (2012). Pediatric First Aid for Caregivers and Teachers (PedFACTS). Jones & Bartlett Publishers. Sep 21. Burlington, MA -Pg 72 Figure 1
2. Arkema. (2006). "Acrylic Sheet Forming Manual" *Plexiglas by Arkema.* <http://www.plexiglas.com/export/sites/plexiglas/.content/medias/downloads/sheet-docs/plexiglas-forming-manual.pdf> (Sept. 27, 2017).
3. Brookfield, Gary. (2010). "Yet Another Elementary Solution of the Brachistochrone Problem." *Mathematics Magazine, 83*(1), 59-63. doi:10.4169/002557010x480017.
4. Building Speed. (2017). "Safety vs. Speed: 2017 Changes to the Chassis." Building Speed, 4 July 2017, buildingspeed.org/blog/2017/02/17/safety-vs-speed-2017-changes-to-the-chassis/.
5. C, Robby. "Hot Wheels Racing League." *Hot Wheels Racing League*, 1 Jan. 1970, www.racehotwheels.com/.
~~4~~6. Chen, R. (2011). Liquid Crystal Displays: Fundamental Physics and Technology (Wiley Series in Display Technology). Hoboken: Wiley. 126-132.
7. Countryside. (2016). "How to Choose A Leg Table, Pedestal Table, or Trestle Table - By Countryside." ~~(21 Jan. 2016).~~ *Countryside Amish Furniture*, <www.countrysideamishfurniture.com/blog/entry/how-to-choose-a-leg-table-pedestal-table-or-trestle-table> (Sept. 23, 2017).
8. Dabe. Brachistochrone curve. (Aug 8, 2016) Thingiverse. MakerBot Industries, LLC https://www.thingiverse.com/thing:1708492
9. Davenport, Tonia. (2009) *Plexi Class: Cutting-edge Projects in Plastic*. First ed., North Light Books, Cincinnati, Pg 14.
10. Elliott, Sara. (2009). "5 Long-Lasting Building Materials." 1. Iron and Steel - 5 Long-Lasting Building Materials | HowStuffWorks, HowStuffWorks, 30 Mar. 2009, home.howstuffworks.com/home-improvement/construction/materials/5-long-lasting-building-materials5.htm.
11. Forest Service. (1974). Wood Handbook: Wood as an Engineering Material. U.S. Department of Agriculture, Forest Products Laboratory, Forest Service, 1974.
~~5~~12. Gabriela R. Sanchis (Elizabethtown College) . Convergence in August of 2007. Historical Activities for Calculus - Module 1: Curve Drawing Then and Now. Mathematical association of America
13. Haws, L., & Kiser, T. (1995). "Exploring the Brachistochrone Problem." *The American Mathematical Monthly, 102*(4), 328-336. doi:10.2307/2974953.
~~6~~*14.* Hill Q. Lauren. (2015). "Understanding the Attention Spans of Elementary Aged Students." *Studydog.* http://www.laurenqhill.com/understanding-the-of-attention-spans-of-elementary-aged-students> (Jan. 8, 2015).

Formatted

Formatted: Outline numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0" + Indent at: 0.3"

Formatted: Heading 2, Space Before: 0 pt

Formatted: Numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0.25" + Indent at: 0.5"

Commented [CTF28]: Created by Daniel

Commented [CTF29]: Created by Chris

Commented [CTF30]: Created by Chris

Formatted: Numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0.25" + Indent at: 0.5"

Commented [c31]: Created by Juan

Formatted: Numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0.25" + Indent at: 0.5"

Commented [CTF32]: Created by william

Formatted: No underline

Formatted: citation_text

Commented [CTF33]: Created by Chris

Commented [CTF34]: Created by Daniel

Commented [CTF35]: Created by Chris

Formatted: Numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0.25" + Indent at: 0.5"

Commented [c36]: Created by Juan

Commented [c37]: Created by Juan

Formatted: Numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0.25" + Indent at: 0.5"

Commented [CTF38]: Created by Daniel

Commented [CTF39]: Created by Chris

Formatted: Default Paragraph Font

Formatted: Heading 6 Char

http://info.ifpan.edu.pl/firststep/aw-works/fsV/parnovsky/parnovsky.pdf

35(3), 1

716. Kenneth E. Moyer, and B. von Haller Gilmer , "The Concept of Attention Spans in Children," The Elementary School Journal 54, no. 8 (Apr., 1954): 464-466.

17. Maxsun. (2017). "Table Bases: A How-to Guide to Find Your Ideal Table Base for Your Restaurant!" (8 Sept. 2017). *Maxsun Group*, <www.maxsungroup.com/table-bases-guide-find-ideal-table-base-restaurant/> (Sept. 23, 2017).

18. Pack. (2009). "Pack 240 Pinewood Derby Track." Pack 240 - Pinewood Derby Track Starting Gate, www.oocities.org/heartland/plains/8340/start.htm.

819. "Patent US6696945 - Video Tripwire." *Google Patents*, Google, 24 Feb. 2004, www.google.com/patents/US6696945.

920. Parnovsky, A. S. (1998). "Some generalizations of brachistochrone problem." *Acta Polonica-Series A General Physics*, *93*, 55-64.

21. Performa. (2011). "Performa · The Geometry of Skateboarding." (2011). *The Geometry of Skateboarding*, <www.performa-arts.org/magazine/entry/the-geometry-of-skateboarding> (Sept. 23, 2017).

22. Reddit. "ELI5: Why Is Stone More Durable than Many Modern Metals? • r/Explainlikeimfive." Reddit, www.reddit.com/r/explainlikeimfive/comments/3axfy1/eli5_why_is_stone_more_durable_than_many_modern/.

1023. Reid, Troy. (2011). *The Complete DIY Solar Panel Guide*. First ed., Lulu.com, Pg 55.

11 White, Ana. "Fancy X Farmhouse Table." (2012). *Ana White | Fancy X Farmhouse Table - DIY Spruce*, <www.thespruce.com/bend-sheet-acrylic-plexiglass-with-tools-2366806> (Sept. 27, 2017).

25. Vsauce. The Brachistochrone. (Jan 21, 2017). Mythbusters' Adam Savage build Brachistochrone. <https://www.youtube.com/watch?v=skvnj67YGmw>

Commented [CTF40]: Created by Chris

Commented [CTF41]: Created by William

Commented [CTF42]: Created by Chris

Commented [c43]: Created by Juan

Commented [CTF44]: Created by Chris

Commented [CTF45]: Created by Chris

Commented [c46]: Created by Juan

Commented [CTF47]: Created by Chris

Formatted: Numbered + Level: 1 + Numbering Style: 1, 2, 3, … + Start at: 1 + Alignment: Left + Aligned at: 0.25" + Indent at: 0.5"

Commented [CTF48]: Created by Chris

Commented [CTF49]: Created by Daniel

12 https://www.thespruce.com/bend-sheet-acrylic-plexiglass-with-tools-2366806

Formatted: Indent: Left: 0.5", No bullets or

6.2 Appendix B: Brainstorming Session 1

Brainstorming Session 1 consisted of a 10-minute unstructured brainstorming session using any alternative solutions for any component of the Brachistochrone as a topic.

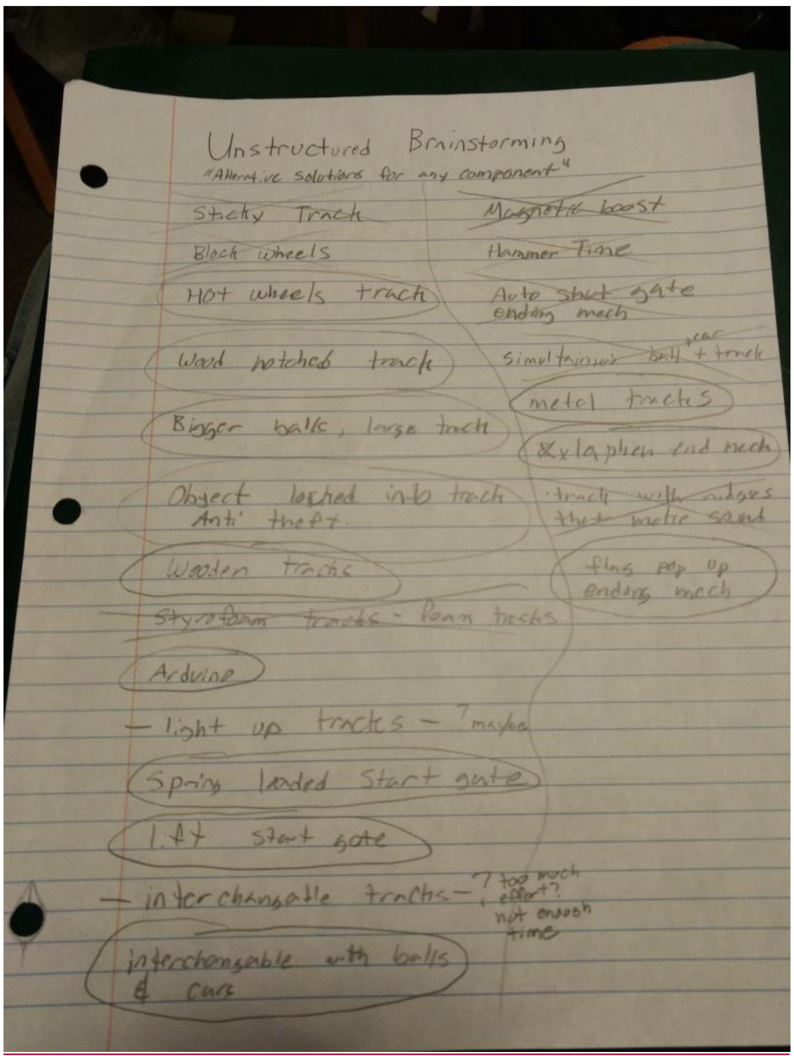


Figure 6-1: Unstructured Brainstorming Session 1 Notes

6.3 Appendix C: Brainstorming Session 2

Brainstorming Session 2 consisted of a 10-minute structured brainstorming session that focused on ideas involving mechanisms, specifically the simultaneous starting mechanism and the finish line placement mechanism.

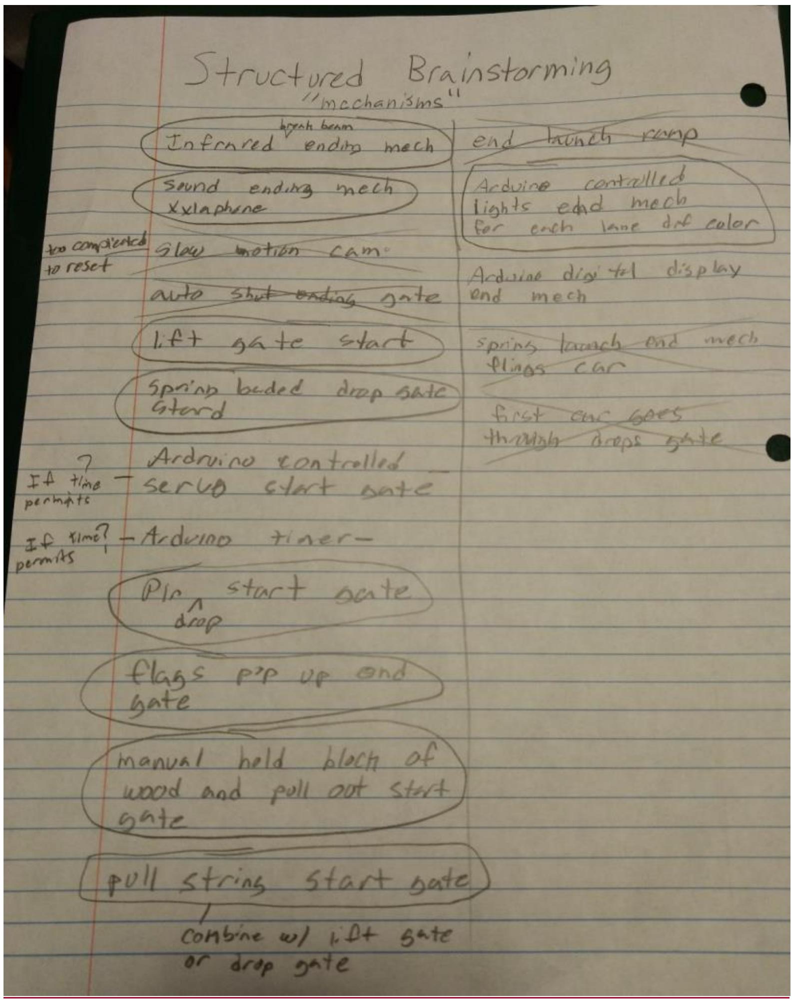


Figure 6-2: Structured Brainstorming Session 2 Notes

6.4 Appendix D: Group Member Project Hours

Fabbri_Chris_TS_E215_FA17			
(all time represented in hours)			
Date	Task Description	Project Time	
		Task	Total
9/16/2017	Timesheet #1 (creation/formatting)	0.0	0.0
9/17/2017	Set up Trello account	0.0	0.0
9/17/2017	Set up team Trello board	1.9	1.9
9/17/2017	Updated Timesheet	0.0	1.9
9/18/2017	Met with group - Section 1 draft	0.9	2.8
9/19/2017	Contacted group/museum and arranged a meeting time	0.4	3.2
9/19/2017	Revised section 1 draft to meet criteria	0.8	4.0
9/19/2017	Created cover memo draft and revised draft document outline	0.8	4.8
9/19/2017	Created a "team google drive" for our team to have shared access	0.3	5.1
9/19/2017	Visited museum with team	2.0	7.1
9/19/2017	Finalized and printed memo/draft documents/section 1 draft	0.2	7.3
9/21/2017	Excel #2	0.0	7.3
9/21/2017	Update Trello	0.3	7.6
9/23/2017	Formatting with Word #1	0.0	7.6
9/23/2017	Research and writing section 2	5.0	12.6
9/24/2017	Check in w/ team - update trello	0.3	12.9
9/25/2017	Meet with client	1.0	13.9
9/26/2017	Meet with 1 team member - work on section 2	3.0	16.9
9/27/2017	Conduct research, finish my assigned sections	2.0	18.9
9/27/2017	Create plan for compilation of all our work, create templates	1.0	19.9
9/27/2017	Format and submit references assignment	0.0	19.9
9/27/2017	Added team members work to Section 2 Draft	0.5	20.4
9/27/2017	Assisted group members with how to update	0.5	20.9
9/27/2017	Recovered lost data and reformatted section 2	0.5	21.4
9/28/2017	Compiled group members research into one coherent doc	2.0	23.4
9/28/2017	Updated trello with current assignments	0.5	23.9
9/30/2017	Finish auto cad assignment 1	0.0	23.9
10/2/2017	Prepare for client meeting - work on criteria	2.0	25.9
10/2/2017	Complete Draft of section 2 - Problem Formation	2.0	27.9
10/3/2017	Meet with group to refine section 2 - Problem Formation	2.5	30.4
10/4/2017	Create photoshop image for Chindogu	0.0	30.4
10/5/2017	Create problem/solution and compile slideshow for Chindogu	0.0	30.4
10/6/2017	Work on creating project Gantt chart w/ gantter.com	1.5	31.9

Formatted Table

10/6/2017	Updated Trello with current assignments	0.3	32.2
10/8/2017	Work on creating Alternative Solution	2.0	34.2
10/8/2017	Finalize Gantt Chart	1.0	35.2
10/8/2017	Formating with word #2	0.0	35.2
10/9/2017	Attempt to meet with client	0.5	35.7
10/10/2017	Created another alternative solution	0.8	36.5
10/10/2017	Attended Weekly Group Meeting Time	3.0	39.5
10/11/2017	Attended extra group meeting time	1.5	41.0
10/11/2017	Took CATME midterm eval test	0.0	41.0
10/11/2017	Worked on Miderm Eval Word Doc	0.0	41.0
10/11/2017	Worked on Alternative Solutions	2.0	43.0
10/12/2017	Finalized and compiled Section 3	1.5	44.5
10/13/2017	Group meeting for planning section 4	0.8	45.2
10/13/2017	Researched Arduino ending mechanism	1.5	46.7
10/14/2017	Created foam prototype of break beam ending mechanism	1.0	47.7
10/15/2017	worked on section 4.4 final decision	2.0	49.7
10/15/2017	Worked on AutoCAD#2	0.0	49.7
10/16/2017	Meet with client	0.8	50.5
10/17/2017	Meet with group	2.0	52.5
10/17/2017	Work on section 4	2.0	54.5
10/18/2017	Meet with group	0.5	55.0
10/18/2017	Research Arduino	1.0	56.0
10/19/2017	finalize and print section 4	1.0	57.0
10/20/2017	Meet with group	0.5	57.5
10/21/2017	create write ups for both pretotypes	1.5	59.0
10/22/2017	Finalize and turn in pretotype writeup	0.5	59.5
10/23/2017	Meet with client	0.7	60.2
10/24/2017	Meet with group	2.0	62.2
10/24/2017	Emailed back and forth with Ken	0.5	62.7
10/25/2017	Meet with group	0.6	63.3
10/27/2017	Meet with group	0.5	63.8
10/27/2017	Work on full size IR Finish Prototype	2.0	65.8
10/27/2017	AutoCAD #3	0.0	65.8
10/28/2017	Finish/Test full size IR Finish Prototype	3.0	68.8
10/28/2017	Finish AutoCAD #3	0.0	68.8
10/29/2017	Create PDF of Prototype # 2 test	0.5	69.3
10/30/2017	Meet with client	1.0	70.3
10/31/2017	Troubleshoot / modify Arduino circuit	1.0	71.3
11/1/2017	Meet with group	0.5	71.8
11/1/2017	bought plywood	0.8	72.6
11/2/2017	brought wood to eureka for CNC cuts	1.0	73.6

11/2/2017	work with group. cut out wood for base and finish gate	2.5	76.1
11/3/2017	met with group	0.5	76.6
11/4/2017	Worked on expanding arduino circuit to 4 lanes/testing	2.0	78.6
11/5/2017	Assembled Finish gate, started wiring electronics	3.0	81.6
11/6/2017	Finished wiring electronics and testing expanded circuit	4.0	85.6
11/7/2017	Put coat of primer on finish gate - rewired and tested	2.0	87.6
11/7/2017	Work on Section 5	3.0	90.6
11/8/2017	Work on construction of project / presentation	5.0	95.6
11/9/2017	Work on presentation	2.0	97.6
11/10/2017	Work on construction of project	9.0	106.6
11/11/2017	Work on construction of project	10.0	116.6
11/12/2017	Work on construction of project	8.0	124.6
11/13/2017	Work on construction of project / Poster / Presentation	3.0	127.6
11/12/2017	Work on Poster / Presentation	5.0	132.6
11/13/2017	Work on Poster Draft and PowerPoint for Presentation	3.0	135.6
11/14/2017	Finish Poster Draft / Paint Ending Mechanism	3.0	138.6
11/14/2017	Test PowerPoint on projector, make modifications to GIFs	2.0	140.6
11/15/2017	Finalize PowerPoint, rehearse speech	3.0	143.6
11/16/2017	Transport project to Presentation and back	1.0	144.6
11/20/2017	Compile all document sections into 1 document	1.0	145.6
11/24/2017	Work on updating/editing section 1 and 2	3.0	148.6
11/26/2017	Work on creating reinternment cover letter and compile receipts	1.0	149.6
11/28/2017	Work on updating and reformatting design document	4.0	153.6
11/29/2017	Painted project	2.0	155.6
11/30/2017	Worked on construction of project	3.5	159.1
11/30/2017	Worked on Project Document	2.0	161.1
12/1/2017	Work on Finalizing Document	4.0	165.1
12/2/2017	Finalize / Print / Bind Document	3.0	168.1
12/2/2017	Paint / Finish Construction	4.0	172.1

Sanchez_Jaun_TS_E215_FA17			
Date	Task Description	Project time (Hours)	
		Task	Total
9/16/2017	Trello	0	0
9/17/2017	Timesheet #1	0	0
9/18/2017	Section 1 draft	1	1
9/19/2017	Scouted client site	1.5	2.5
9/19/2017	Finalized Documents (cover and section 1)	0.75	3.25
9/19/2017	Went to discovery Museum with team	2	5.25

Formatted: Spanish (Mexico)

Formatted Table

9/20/2017	Nothing this day	0	5.25
9/21/2017	Excel #2	0	5.25
9/22/2017	Nothing this day	0	5.25
9/23/2017	Formatting Writting	3	8.25
9/24/2017	More research for topics	2	10.25
9/25/2017	Meet With Client	1	11.25
9/26/2017	Literature Review	3	14.25
9/27/2017	Literature Review	0	14.25
9/28/2017	Individual References	0	14.25
9/28/2017	Autocad 1	0	14.25
9/29/2017	Autocad 1	0	14.25
9/30/2017	Nothing this day	0	14.25
10/1/2017	Timesheet #1	0	14.25
10/2/2017	Auto Cad 1	0	14.25
10/3/2017	Section 2 draft	1.5	15.75
10/4/2017	working on chindogue presentation	0	15.75
10/5/2017	Alternative solutions	0	15.75
10/6/2017	Word #2	0	15.75
10/7/2017	Gantt Chart	0.5	16.25
10/8/2017	Gantt Chart	0.5	16.75
10/9/2017	Nothing this day	0	16.75
10/10/2017	met with chris and worked on section 3	3	19.75
10/11/2017	Section 3 brain storm/write	0	19.75
10/12/2017	AutoCad 2	0	19.75
10/13/2017	Group meeting/ section 4 work	2.25	22
10/14/2017	AutoCad 2	0	22
10/15/2017	Section 4	2	24
10/16/2017	Met with Client	0.5	24.5
10/17/2017	Met with Team	2	26.5
10/18/2017	worked on section 4	1	27.5
10/19/2017	meeting with team went over final ideas/prototyped track	4	31.5
10/20/2017	met with team	1	32.5
10/21/2017	nothing this day	0	32.5
10/22/2017	Nothing this day	0	32.5
10/23/2017	Met with client	0.5	33
10/24/2017	Meeting with team, going over materials and building style	2	35
10/25/2017	meet with chris and called places for wood donations	1	36
10/26/2017	Auto cad 3	3.5	39.5
10/27/2017	contacted more wood places and went to Daniels to chechout wood	1	40.5
10/28/2017	Nothing this day	0	40.5
10/29/2017	Auto Cad 3 and prototyped start mechanism	3	43.5
10/30/2017	Met with client went/ email about what we need wood wise	1	44.5
10/31/2017	Meet with group	2	46.5
11/1/2017	Went with chris to get wood	0	46.5
11/2/2017	Re-exported all files from cad 3 to be used for cnc machine/ worked with group did major cuts	8	54.5

11/3/2017	met with group worked with CNC partners	2	56.5
11/4/2017	did nothing this day	0	56.5
11/5/2017	prototyped	2	58.5
11/6/2017	Cut more cuts for the project	2	60.5
11/7/2017	worked on section 5	0.5	61
11/8/2017	worked on construction of project	5	66
11/9/2017	Worked on presentation	2	68
11/10/2017	worked on project	6	74
11/11/2017	at work	0	74
11/12/2017	worked on project	4	78
11/13/2017	poster draft and powerpoint	5	83
11/14/2017	worked on project	2	85
11/15/2017	worked on presentation	3	88
11/16/2017	transported project	0.5	88.5
11/17/2017	wrote to people who helped us	0.5	89
11/18/2017	Nothing this day	0	89
11/19/2017	Nothing this day	0	89
11/20/2017	Nothing this day	0	89
11/21/2017	Nothing this day	0	89
11/22/2017	Nothing this day	0	89
11/23/2017	Nothing this day	0	89
11/24/2017	worked on final doc	1	90
11/25/2017	worked on final doc	1	91
11/26/2017	Nothing this day	0	91
11/27/2017	met with group and got a schedule for week	1	92
11/28/2017	Met with Group	4	96
11/29/2017	worked document	3	99
11/30/2017	sanded and repainted	3	102
12/1/2017	worked on document	2	104

Daniel Hodges			
Date	**Task**	**Project Time (hr)**	
		Task	**Total**
9/14/2017	Group brainstorm	1	1
9/17/2017	Excel Time Sheet	0	1
			1
			1
10/3/2017	Problem Analysis	1.5	2.5
10/6/2017	Word 2		2.5
10/13/2017	Group Meeting	1	3.5
10/16/2017	CAD 2		3.5
10/16/2017	Section 4.4	1	4.5
10/20/2017	Group Meeting	0.5	5
10/23/2017	Prototyping	1.5	6.5

10/24/2017	Wood Pickup	2	8.5
10/25/2017	Group Meeting	2	10.5
10/26/2107	Prototyping	1	11.5
10/26/2017	CAD 3	_	11.5
10/27/2017	Prototyping	1	12.5
10/27/2017	CAD 3	_	12.5
10/30/2017	Shop Work	2	14.5
11/5/2017	Shop Work	2	16.5
11/6/2017	Shop Work	1	17.5
11/7/2017	practice presentation	3	20.5
11/8/2017	practice presentation	6	26.5
11/13/2017	Poster Design	2	28.5
11/13/2017	Shop Work	2	30.5
11/14/2017	Poster Design	2	32.5
11/15/2017	Presentation Practice	2	34.5
11/16/2017	presentation prep	1	35.5
11/27/2017	Poster Design	1	36.5
11/28/2017	painting Project	1	37.5
11/28/2017	painting Project	1	38.5

William Nitzsche

Date	Task Description	Project Time (hr)	
_	_	Task	Total
10/15	Timesheet	0	0
10/16	Autocad	0	0
10/17	Design brainstorm	0.5	0
10/18	Alternative Solutions	3	3.5
10/19	Word #2	0	3.5
10/20	Team eval	1	4.5

X