SOCIETY OF PHYSICS STUDENTS
An organization of the American Institute of Physics

Marsh W. White Award Report

Project Proposal Title	The Giant Brachistochrone of SCIENCE!
Name of School	University of Central Arkansas
SPS Chapter Number	1059
Project Leads	John Ferrier (jpferrierjr@gmail.com) and Seth Thomas (bst03001@gmail.com)
Additional Project Leads	Max Milan (maxmilan4@gmail.com) and Catherine Mason (cmason5@uca.edu)
SPS Chapter Advisors	Dr. William Slaton and Dr. Azida Walker
Total Amount Received from SPS	$300.00
Total Amount Expended from SPS	$250.00 (to date)

Summary of Award Activities

Society of Physics Students from the University of Central Arkansas designed and built a large, mobile brachistochrone for use in outreach demo shows, recruitment events, and in-classroom instruction. The brachistochrone is scheduled to be showcased during the UCA Physics demo show season beginning in Spring 2015, and in upcoming classes, beginning later in the year.

Statement of Activity

Overview of Award Activity

Brief Description

Our chapter wanted to build a large, mobile brachistochrone for use in our outreach demo shows for elementary students, recruitment events, and in-class demonstrations at the university level. A brachistochrone demonstrates that the shortest path between two points (a straight line) is not necessarily the shortest time between two points – for that, you need a special curve called the cycloid. The brachistochrone demonstrates this non-intuitive result and can be used to inspire students in the general public or particular students studying mechanics or calculus of variations.

Our chapter performed science demonstrations for over 900 local children last year, and there's a high demand every year from more and more school teachers for more and more shows. We wanted to update our demos with a new addition – the brachistochrone. The brachistochrone would not only be used in demo shows for children, but also for recruiting events and for in-classroom use in future mechanics or calculus classes.

Outcomes

After we submitted our initial design and received the award funds, we discovered that our original model had a significant flaw: its weight and bulk would have prevented the brachistochrone from being as mobile as we had intended. Classes were wrapping up when we discovered this flaw so we took up the task of coming up with a new design in late August. By late September, we agreed to try a support and track model, and by October we had produced a working prototype.

To produce the brachistochrone at the scale we were looking for, we wrote a Python code to model different track designs, calculate their build specifications and build limitations, and run a small simulation on how various tracks would perform. This program calculated essential details later used during the construction phase – the heights of each support, the support positions along the base, the slope of each support top that was required to conform to the track, the overall track lengths, etc. – and to forestall potential problems. Such problems included adjusting the model to meet materials and tools available at hand and determining the best possible design based on calculated performance data. Construction was started in early December and was finished by mid December.

In designing the electronics of the Brachistochrone ramp, the strategy was specifically planned to be dynamic. The track will have photo sensitive sensors that the balls roll over in order to tell the electronics the position and average velocity of the relative ball. A sensor will be placed on each dowel to ensure proper x-directional spacing to allow for accurate calculations and modeling. In addition to the sensors, the electronic system will have a large punch button for children interacting with the demo. This button releases the ball and initiates the measurements of the sensors and resets the measurements upon completion. The ball hold will consist of an electromagnet that remains on while the system is powered and the punch button has not been pushed. Finally, at the end of the ramp, LEDs will be placed to signify the winner of the race. The components are not currently installed since they have been ordered and have not arrived as of writing. Using similar components that were found around the lab for testing, the code that will monitor the sensors has already been developed.

The dynamic part of the track electronics comes in with the specific controllers used. Currently, for simplicity and time, the track is designed to be controlled by an Arduino UNO. Keeping our sensors essentially digital, we will be able to easily expand upon this project and move from an Arduino to a Raspberry Pi. In using the Pi, we'll be able to properly show real-time analysis of the positions, velocities, and energy states of the balls. Eventually, we want to expand capabilities of the ramp to include an installed screen that will simultaneously calculate all associated properties of the motion. This feature will be used in our Mechanics course to show measured versus calculated values.

We have finished the brachistochrone but because our demo season occurs in the spring, we'll have to wait until then for a more concise outcome analysis. If last year's success is any predictor for the coming spring, we predict however to reach over 900 students. Also, our university will likely offer a mechanics course in Fall 2015, so we'll be able to demonstrate it again then.

Audience

This project was designed with a large range of audience: local elementary students; students, in general, at recruiting events; and upper-level university students studying mechanics.

Context of the Project

Demo shows designed for physics outreach have been a huge success in recent years. New demonstrations are intended to provide novelty and heighten interest in science.

Impact Assessment: How the Project/Activity/Event Promoted Interest in Physics

We won't be able to fully assess how this project has promoted interest in physics until we deploy it in demo shows, and that won't happen until spring 2015. However, the design and building of this project has caused our local chapter to grow and try new things. We formed a new committee in order to address projects like the brachistochrone, where there is a necessity to design a project and see it through to completion. This committee, composed mostly of SPS students, now meets weekly to discuss ideas about potential build projects and to share insight and support in order to make those ideas into reality. While this has only been our first semester, the members of our committee have already demonstrated interest and increased activity at regular SPS meetings and committee meetings.

This task has also forced our local SPS chapter to learn new skills – programming skills, woodworking skills, mathematical skills, engineering skills, etc. Most of these new skills were entirely unanticipated at the start of the project. Therefore, as of writing and in the hopes of fully implementing the brachistochrone in its intended venues, we can confidently say that the project has been a success because of how much our SPS team has grown.

Key Metrics and Reflection

Who was the target audience of your project?	Elementary students as part of our yearly outreach program; college students studying classical mechanics; potential recruits for the department of Physics and Astronomy
How many attendees/participants were directly impacted by your project? Please describe them (for example, "50 third grade students" or "25 families.").	Estimate: For upcoming year 2015, approximately 900 elementary students and 20 college students enrolled in classical mechanics, not to mention many at our annual recruiting events.
How many students from your SPS chapter were involved in the activity, and in what capacity?	2 were directly involved in all stages of the process, from conception to construction. 2 were involved in prototype testing. 7-8 others were involved on an advisory basis.
Was the amount of money you received form SPS sufficient to carry out the activities outlined in your proposal? Could you have used additional funding? If yes, how much would you have liked and how would the additional funding have augmented your activity?	The amount of funding was sufficient to build the brachistochrone, as we had originally envisioned it. Additionally funding could have been used for further testing and research on the brachistochrone; specifically, whether or not other curves could hold up well against the cycloid.
Do you anticipate repeating this project/activity/event in the future, or having a follow-up project/activity/event? If yes, please describe.	We plan on incorporating this project in our upcoming demo show season, at recruiting events, and in future mechanics classes.
What new relationships did you build through this project?	We created a new committee to handle projects like this in the future. The committee, composed of SPS students, meets regularly to discuss potential build projects and to share advice and expertise.
If you were to do your project again, what would you do differently?	We would have liked to have done more analytic work on the front end – just to know a little bit more on how the project would have performed. Also, time and costs permitting, we would have liked to have built an additional prototype.

Expenditures

Expenditure Table

Item	Cost
Prototype	$ 10.00
Poplar Board	90.00
Dowel Rods	50.00
Wood Glue	4.00
Drop Cloth	3.00
Nails and Screws	18.25
Drill Head	10.00
Tax	15.75
Arduino Circuit and Components	49.00
Subtotal	$ 250.00
Planned	
Additional Circuit Components	15.00
Electro magnets	15.00
Steel Balls	4.00
Wood stain	5.00
Anticipated Total	$ 289.00

Activity Photos

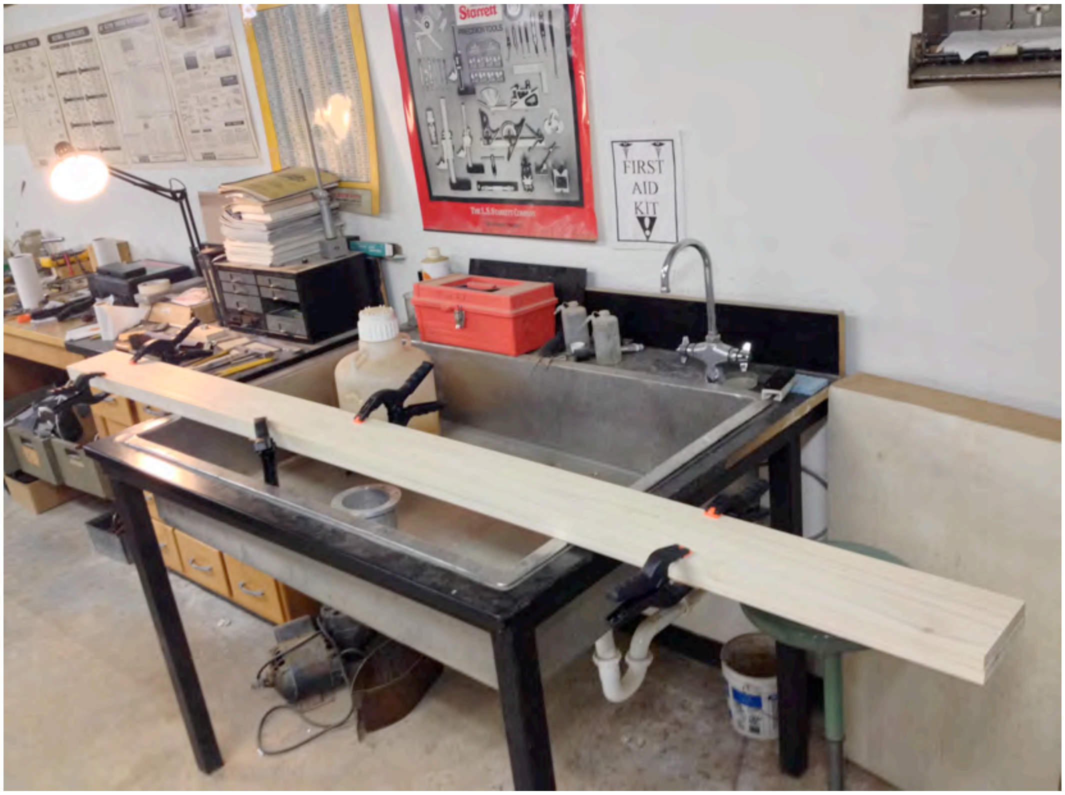

Figure 1: Preparing the base

Figure 2: Cutting the supports

Figure 3: Supports cut

Figure 4: Creating support holes with a drill press

Figure 5: Support test

Figure 6: Leveling supports and track test

Figure 7: Tracks assembled

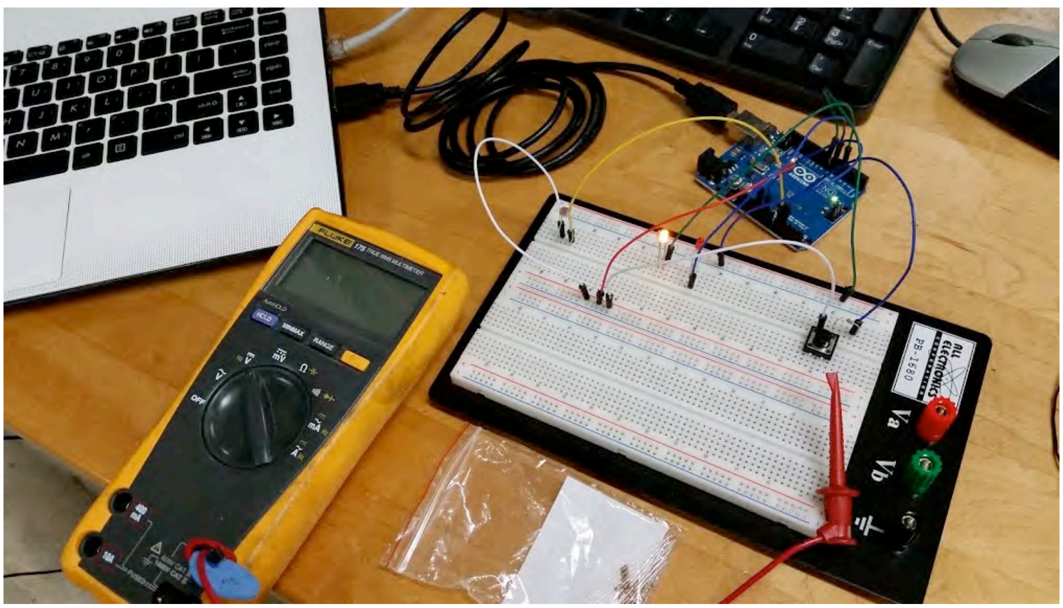

Figure 8: Building the electronics for the ramp


Figure 9: Tracks assembled (viewed from the bottom)

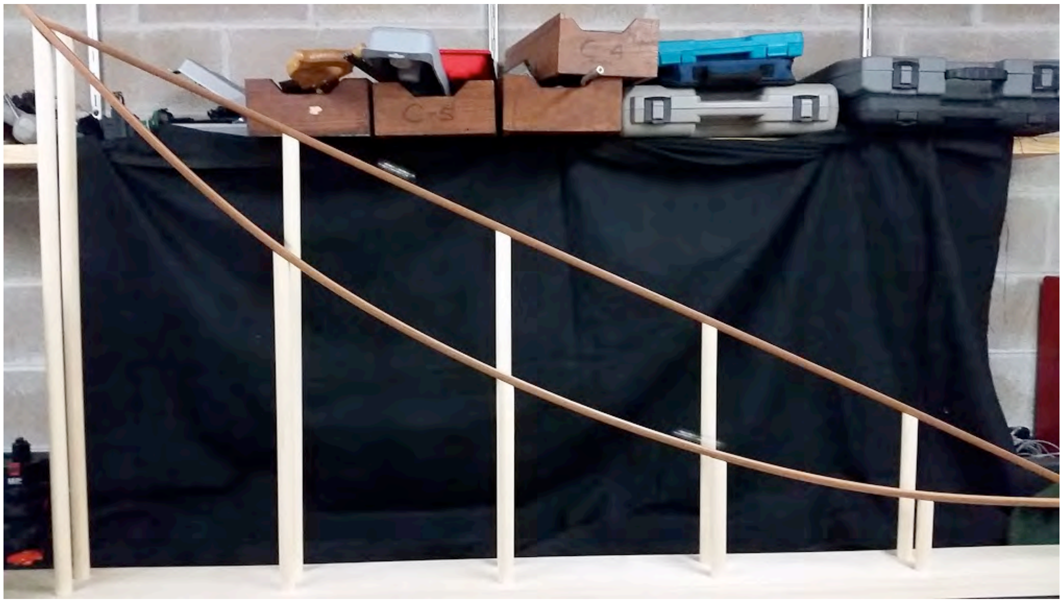

Figure 10: Balls in motion

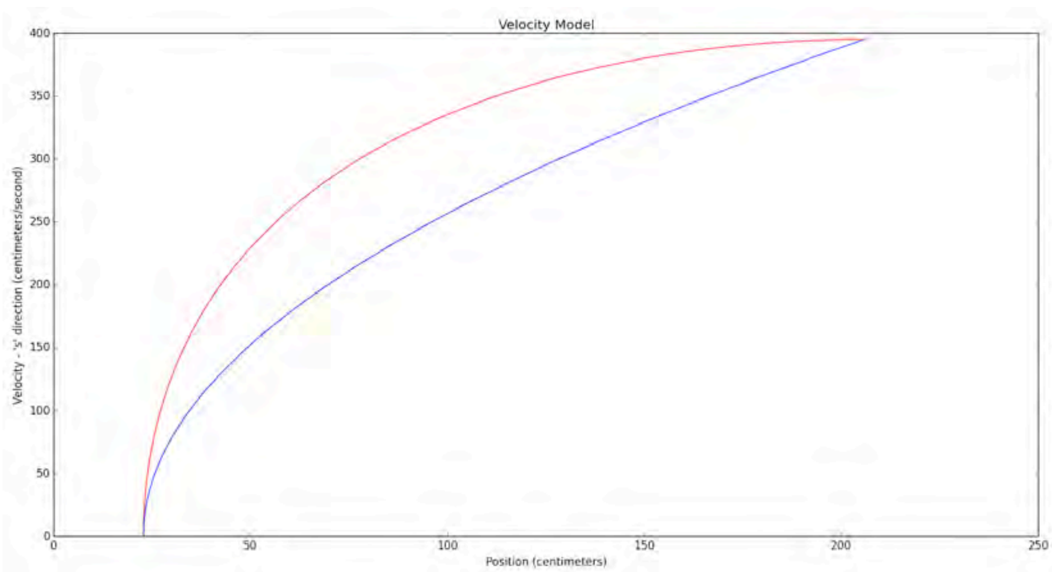

Figure 11: Predicted velocities of balls rolling along these tracks as a function of position. The top red line represents the cycloid, while the bottom blue line represents the straight path.

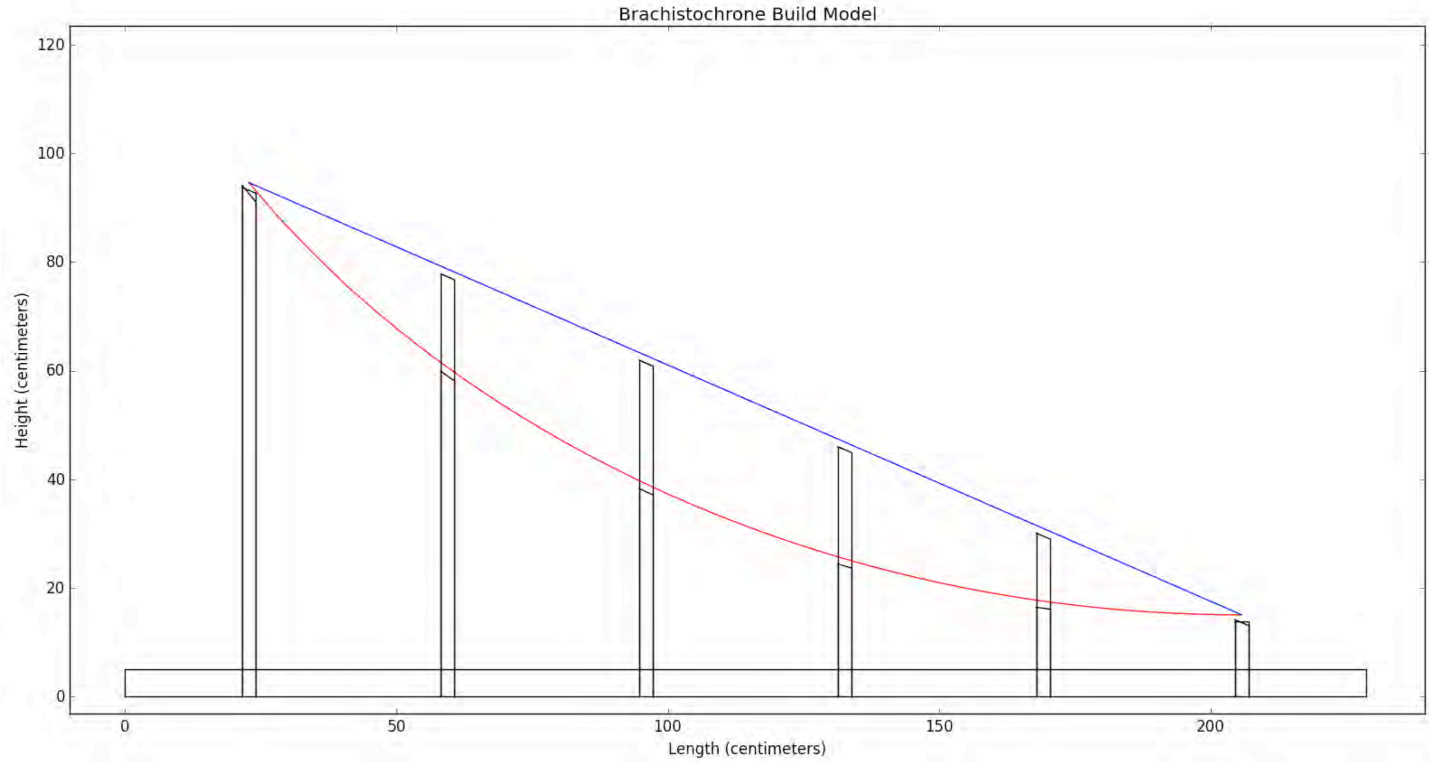

Figure 12: Build model

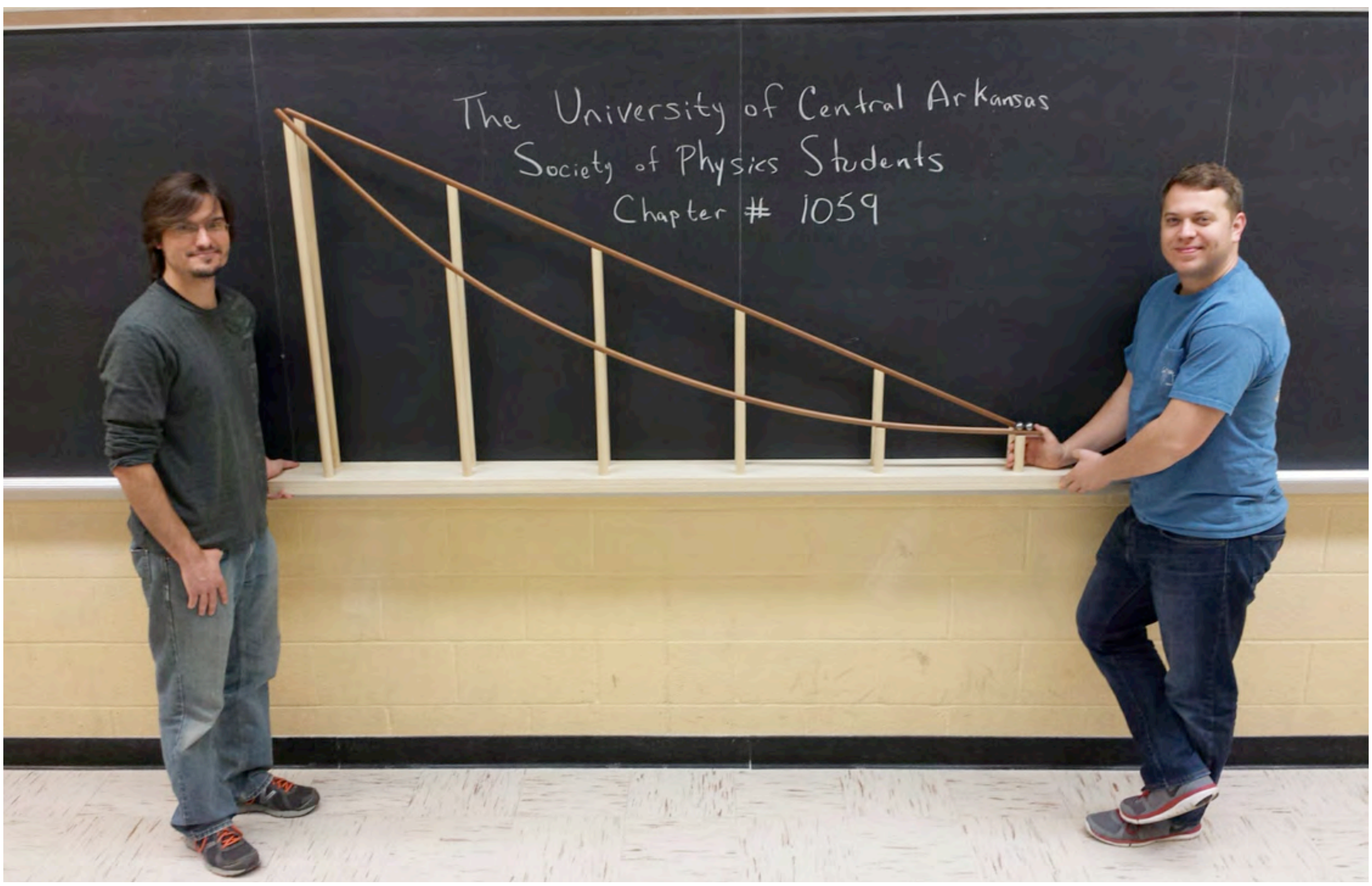

Figure 13: Completed Brachistochrone