SOCIETY OF PHYSICS STUDENTS
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SPS Chapter Research Award Final Report

Project Title	A cloud chamber for academic and outreach purposes
Name of School	Goucher College
SPS Chapter Number	2501
Total Amount Awarded	$1230
Total Amount Expended	$1069.43
Project Leader	Phoebe Yeoh/Chloe Gooditis

Abstract

The students of Goucher College Physics and Astronomy Department plan to design and construct a working cloud chamber. Through the project, they will develop valuable scientific skills while creating a permanent piece of equipment to be used in the classroom as well as for outreach programs.

Statement of Activity

Overview of Award Activity

Our project is to design and construction of a cloud chamber, which is an instrument used to detect and visibly show the tracks of charged particles. Once completed, the chamber is to be used for academic study in our modern physics teaching laboratory, as well as outreach with local high schools.

In the 2014 fall semester, two new members of physics club became heavily involved in the cloud chamber project. The first is a first year physics major, and the second is a sophomore chemistry major who has experience in working on scientific projects such as the cloud chamber. The remaining participants on the project are all SPS members who joined physics club last year as first year students, all of whom are now sophomore physics majors. The first few weeks of the semester were spent recruiting and orienting new members to the physics club and following up on work done over the summer. Following that, we brought our new members up to speed about the cloud chamber's progress and also followed a thorough planning process in

which we laid out the details of what we had accomplished to that point, and then revised and updated some of the plans we had made in the past semester, particularly regarding the electrical work.

At the end of spring 2014, we had already collaboratively completed the shelving units with which the thermoelectric coolers would be supported, the box to hold the various electrical and water pipes, and the viewing tank. By the end of fall 2014, we had installed the shelving units into the base, connected the water tubing within the base, cut down the piece of anodized aluminum, and started the electrical work. We were not able to fully complete the electrical work because the GFI we had bought was found to be defective, and at the end of the semester there was not have enough time return and replace it.

Due to the extension we were given, we were able to successfully complete the building of the cloud chamber. First, we finished connecting the water piping to the CPU coolers and the aquarium tank, and then tested the water system. Some leaks were discovered and then quickly remedied. Next we wired the power supplies to the thermoelectric coolers, which are place on top of the CPU coolers within the chamber base. We observed safety precautions to separate the water pipes and the electrical wires by securing the electrical wires onto the walls of the base, and directing the pipes and wires though separate exit holes. Finally, we collected the necessary supplies to run the cloud chamber, such as removable caulk, alcohol, and felt. This concluded the actual construction of the cloud chamber.

Description of Research - Methods, Design, and Procedures

After we finished the construction of the chamber, we attempted to test the equipment. However, we ran into equipment failure when we began to run tests using the thermoelectric coolers. Although in the specifications of the coolers it was stated that they would run successfully to 10 amps, when we connected them initially to our power supplies the coolers would heat on both sides to remarkable temperatures. We then began to test the thermoelectrics using low voltage power supplies, and found that each performed successfully up to 4 volts, which was a current far lower than we had been expecting to run.

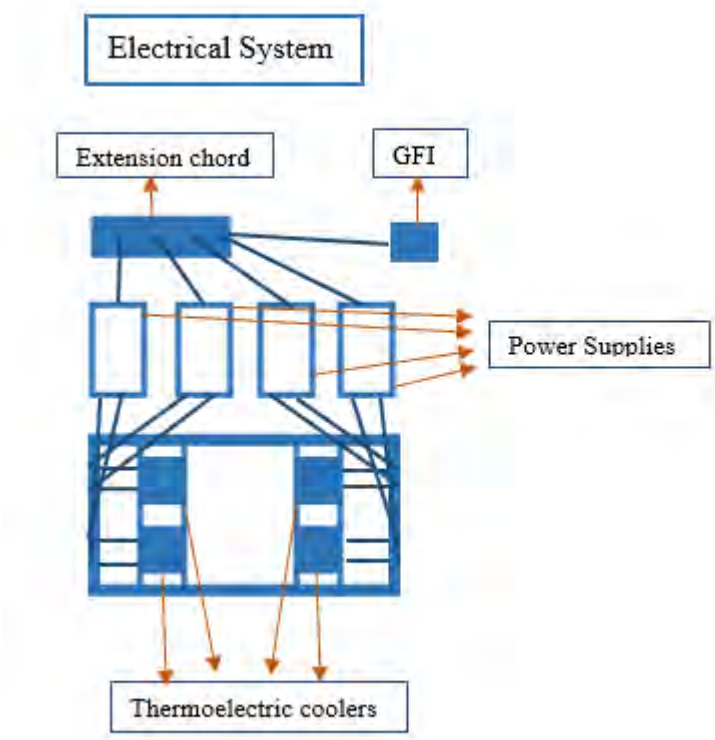
It was suggested to us by our advisor that perhaps the thermoelectrics were failing because they did not have a great enough temperature difference between the sides. Therefore, we next ran the thermoelectrics with our high-voltage power supplies while one side was being cooled by the CPU coolers with ice water running through. This was unsuccessful, as the thermoelectrics immediately began to overheat. We then attempted running the thermoelectrics at lower voltages while being cooled by ice water, but still were unsuccessful in achieving cooling. Lastly, we tested the resistance of each of the thermoelectrics. The specifications of the coolers stated a resistance of 2 Ohms, but in our testing, three of the coolers had a resistance of 2.5 Ohms, and one of nearly 4 Ohms. Even though three of the thermoelectrics should be close to specs, we are still not seeing the performance we should, and the last thermoelectric seems to have been burnt out so we intend to replace it eventually.

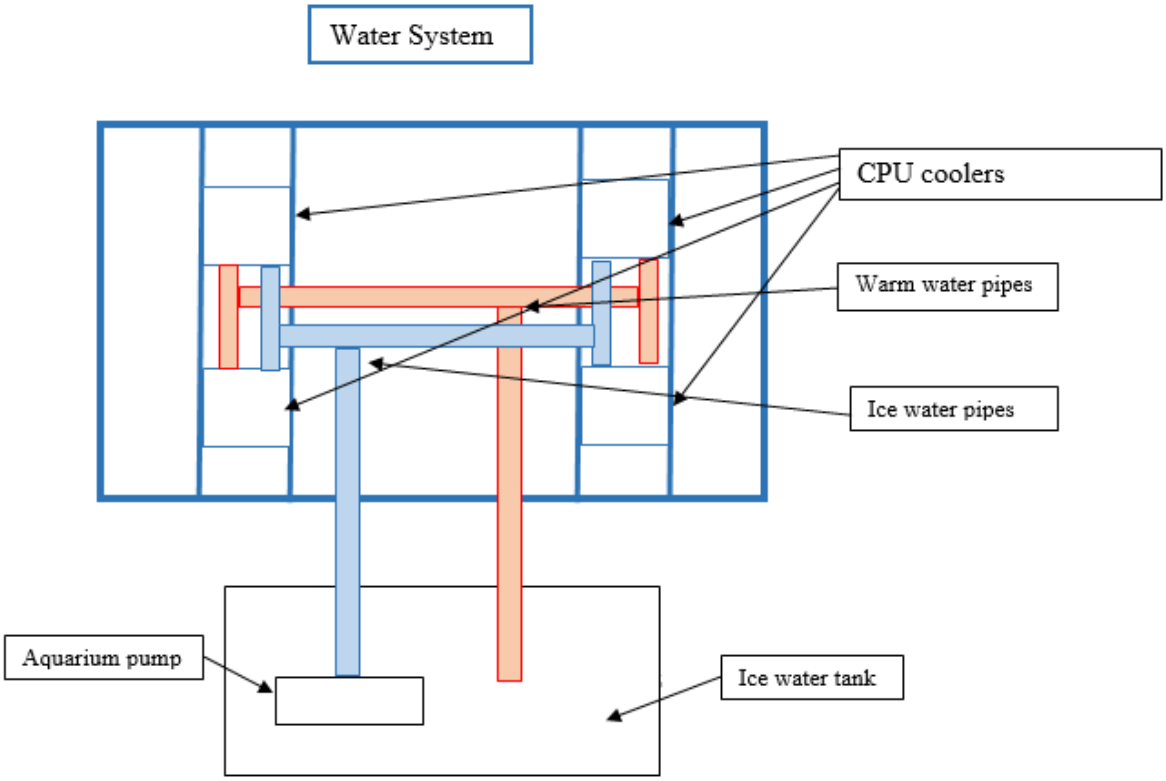
Because we lacked the funds to purchase new thermoelectric coolers, we then attempted to cool the chamber using only ice water, but were only able to reach approximately 40 degrees Fahrenheit, which is far warmer than the temperature needed to achieve condensation in order to see particle trails. It was suggested by a club member to use dry ice to cool the chamber, but it was decided that using a system other than the one designed

would be untrue to the goals of our research. In the future we plan to continue troubleshooting with our unreliable thermoelectric coolers until we can raise funds to purchase new ones. Therefore the project will extend into the 2015-2016 school year, and we hope by next spring to have successfully been able to cool down to temperatures where we can hold successful testing.

As our project was to design and construct a cloud chamber, we have attached some diagrams of the electrical and water cooling systems central to the cloud chamber. We designed many parts of the chamber to be removable and easily taken apart (for example, the shelves holding up the cooling equipment are removable and held in place by L-brackets, and the back of the chamber is removable) so that maintenance and further design modifications can be made down the road if necessary. Dr Rodney Yoder, our project advisor, also helped us greatly with the design of the electrical work. Amongst other suggestions, he suggested using an extension cord power strip to easily connect our power supplies in parallel to a GFI (which is included for safety reasons, in case the water cooling system breaks and water contacts the electrical system during operation).

Future design modifications and additions may involve building a tower to contain the power supplies, and creating a top that will fit around the viewing tank while hiding the inside of the chamber from view.
Electrical and water system diagrams:





Discussion of Results

Pictures of what we have completed thus far are attached at the bottom of this report. To this point, we have finished the construction of the cloud chamber and begun to test and troubleshoot our equipment. Our results of testing the thermoelectrics have been discouraging, as they have not followed specifications and therefore have failed to perform what we require. Because of this equipment failure, we have not been able to fully cool down the chamber to the level needed to view particle tracks.

However, due to the lack of success with our current electrical system, we next plan to place resistance between the electrical power supplies and the thermoelectrics in the hope that with less current the supplies will be able to perform as hoped. If not, we plan to raise funds and invest in new thermoelectric coolers in order to finalize the project. Therefore, the project will extend through the next school year, when we will hopefully obtain more exciting results.

Dissemination of Results

Because the cloud chamber is still in progress, we have not yet disseminated any results pertaining to the use of the chamber. However, as stated above we have told prospective students about the chamber, and the head of our department has written an article about the project. Also, we are presenting the project to a journalist who will write about it in the Goucher Quarterly, which is our school's alumni magazine. In the future, we hope to put together a full presentation for students to learn about it. After we have fixed our current equipment and are

able to obtain results, we plan to compare our project to those of clubs at other schools, and perhaps to present at conferences in our area.

Impact Assessment:

How the Project Influenced your Chapter

Overall, this project has brought us closer as a chapter. We have spent the majority of our weekly meetings (which last between two and three hours) planning the cloud chamber or working on it collaboratively. However, we did find that only spending our weekly meetings working on the project was not enough time to dedicate to the project, as it was sometimes difficult to pick up immediately from where we left off in past weeks. We tried to mitigate this by planning out meeting agendas beforehand, but meetings were still not as organized as we would have liked, especially as we encountered multiple setbacks in construction. However, the discussion and collaboration among those of us on the cloud chamber team brought us very close together, which was especially valuable between physics majors of different years. This project helped to weave ties between new students and experienced students, giving older students the opportunity to mentor and lead, and younger students the chance to gain confidence on a non-academic project.

Of the two new members we recruited, one is a freshman named Sam who enrolled at Goucher in part because he was interested in the cloud chamber. Our department head, Dr. Sugerman, told him about the opportunity to work on the cloud chamber during an admitted students' day. Sam has been heavily involved in designing and building the cloud chamber, which we see as a successful manifestation of the project's intent to teach underclassmen research-related skills. We are also glad that it has been used as a recruiting tool, and Dr. Sugerman continues to let prospective students know about the project. In this way, we hope to continue increasing the number of physics majors at Goucher while maintaining a steady amount of students interested in working on the cloud chamber.

Future work, which will be headed primarily by Chloe Gooditis '16 for the year 2015-2016, will involve testing the chamber, improving on its design and making documentation for its usage, as Phoebe Yeoh is a graduating senior. We are also making plans to continue handing down the project to other underclassmen as necessary.

If we could give any advice to chapters applying for SPS research awards, it would be to have a realistic timeline of what can be accomplished in one year, and to account for extra time needed for potential setbacks. For example, our original proposal called for starting the project right at the end of January, whereas due to funds distribution and buying equipment we were only able to start the project around mid-March.

Overall, we are incredibly grateful to Sigma Pi Sigma for funding our project. It has successfully created opportunities for student involvement, recruitment and leadership in our department, and we are sure that it will continue to do so.

Key Metrics and Reflection

How many students from your SPS chapter were involved in the research, and in what capacity?	6 students were involved in 2013-2014 and 7 students have been involved in 2014-2015.
Was the amount of money you received from 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? How would the additional funding have augmented your activity?	The amount of money has been sufficient, in part because we were able to receive a free aluminum piece and put some of the funding towards unanticipated expenses.
Do you anticipate continuing or expanding on this research project in the future? If yes, please explain.	Future work will involve testing, refinining the design and planning its usage in outreach as well as for a classroom apparatus.
If you were to do your project again, what would you do differently?	Have a more organized planning process, and arrange for meetings to be more often than once a week.

Press Coverage (if applicable)

On the Goucher Physics Department's webpage:
http://www.goucher.edu/academics/physics-and-astronomy/physics-and-astronomy-news/cloud-chamber

An article will be appearing in the Goucher Quarterly, which is our alumni magazine, on the project.

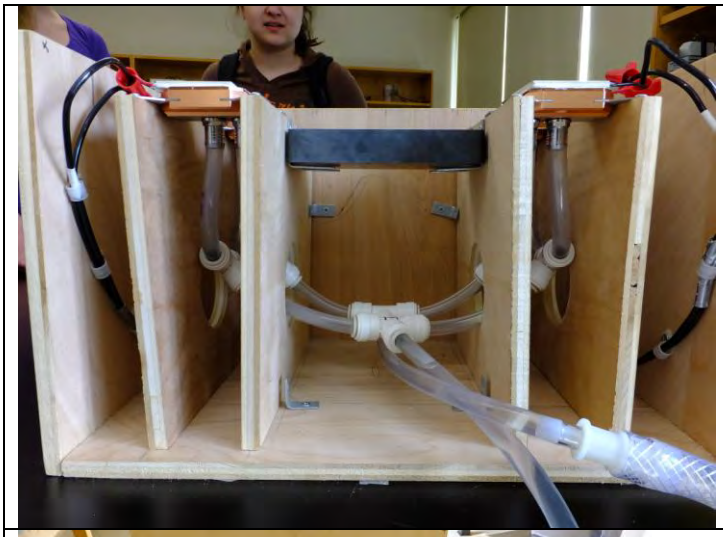
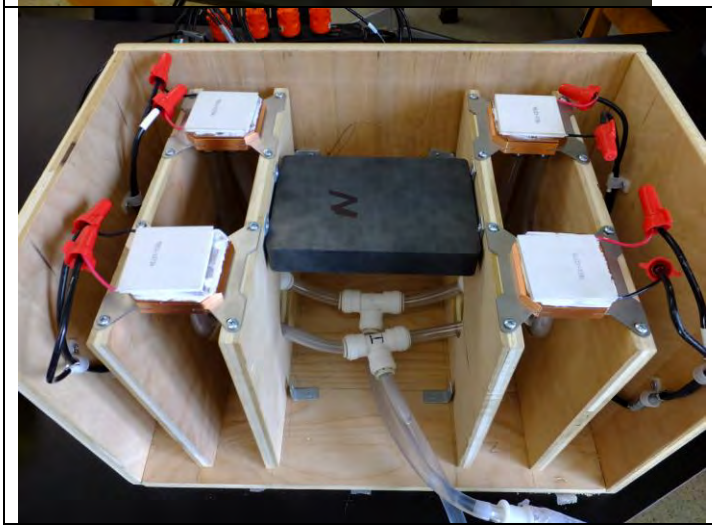
The SPS observer has also mentioned our project in brief in several issues.

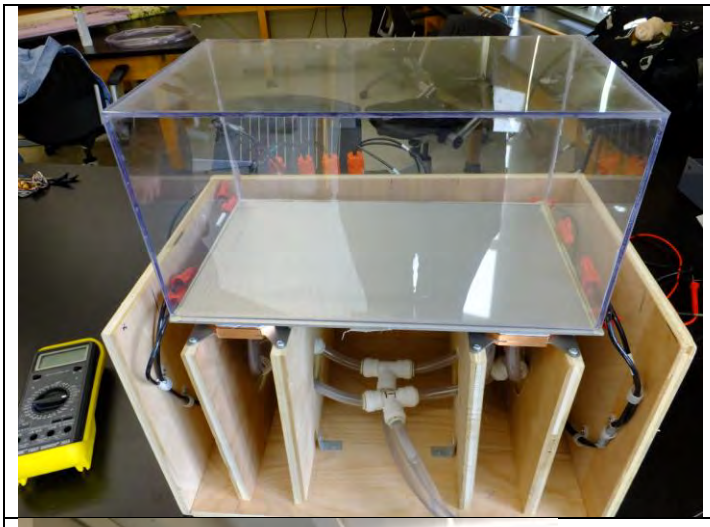
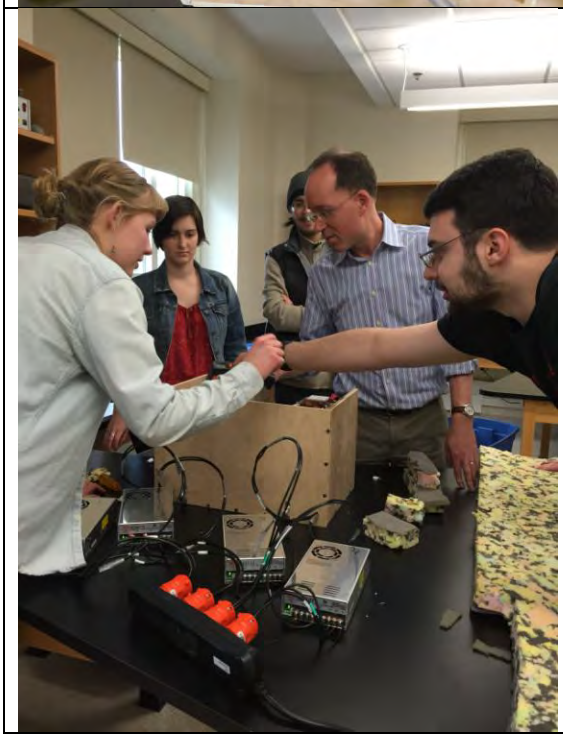
Expenditures

Expenditure Table

Item	Please explain how this expense relates to your project as outlined in your proposal.	Cost
4 Meanwell Power Supplies	Power supplies	$239.80
4 TEC1-12726 Thermoelectric Coolers	Chamber cooling system	$100
4 Heatkiller rev 3.0 CPU liquid cooling blocks	Chamber cooling system	$339.80
8 ¼" barb fittings (for CPU coolers)	Chamber cooling system	$23.92
1 lifeguard aquatic water pump (2200)	Chamber cooling system	$47.61
Lexan polycarbonate sheets	Viewing tank	$45.91
Rare earth magnet		$7.85
Miscellaneous expenses from Home Depot/other retailers	(10-gauge stranded wire, wingnut wire connectors, Loctite superglue for viewing tank, insulation, wood, hose fittings for cooling blocks, barbed T-connectors and hose adapters, vinyl hose tubing, screws, drill bits, GFI, plugs, L-brackets)	$242.91
Newegg p3 electricity meter		$21.73
Total of Expenses Covered by SPS Funding		1069.43

Activity Photos

	Figure 1: the water cooling system attached to shelving. L-brackets are supporting the magnet from underneath.
	Figure 2: The power supplies and electrical work. The wires feed into the cloud chamber through small holes in the back.
	Figure 3: the thermoelectrics on top of chip coolers. The north side of the magnet is facing up.

	**Figure 4: The chamber and aluminum plate resting on the cooling system.**
	**Figure 5: Physics club members with advisor at work on the project.**