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Project Proposal:

Reduction of Snow and Ice Accumulation on Stairs Through Heated Paneling

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Introduction and Problem Definition:

Safety is a great concern for all universities alike. Ensuring that their paying students and staff can have unrestricted access to administrative and educational buildings without fear of injury. Specifically, on the St. Francis Xavier University campus ice and snow accumulation cause hazardous walking conditions for the students. While the walking pathways are efficiently cleared by plows, the stairs around campus must be manually shoveled. Not only does this require a great amount of time and labor, students can attest to the fact that the stairs on campus are rarely cleared to a safe standard. Many students over the recent winter months have slipped and fallen while using these stairs. Whether the cause be from ice or snow that has been packed down and become slippery, conditions like this make walking to class a danger.

To gain more understanding of the impact on students, a survey was conducted over the course of five days. The initial question was “Have you or someone you know slipped on the stairs around campus?”. With a total of 110 responses, 70% of people claim they had fallen on stairs around campus. Following up with the students who had fallen, it was found that 48.1% who answered yes to the first question were slightly injured after slipping. Even more shocking is the fact that 10.4% claimed they were injured to the extent of seeing a nurse or doctor. These statistics show that slippery stairs around campus impact many students.

Proposed solution:

With the issue at hand, a solution is needed to effectively remove snow in a way that would prevent students from further injuries. The best solution to prevent anyone else slipping and possibly harming themselves, is to implement a paneled heating system, titled the Solar Step. The idea of the Solar Step is that removable panels would be installed to problematic stairs around campus during the winter months. These panels would be heated in order to efficiently prevent ice and snow build up. This would eliminate the need for manual snow removal or salting. Thus, the Solar Step would provide a more effective way to combat ice and snow accumulation. When not in use during the warmer months, the panels can be safely stored as to reduce exposure and increase the lifespan.

The top side of the panels will include heated wires or elements to distribute heat evenly across the surface. It will not be necessary for the surface to be hot, a temperature slightly above the freezing point of water will be effective in clearing any snow or ice. The panels will be made of durable material as students will be allowed to walk on the panels while in use. After looking at different activation sensors, it was concluded that the best way to activate the panels is through a manual switch.

As the name implies, the Solar Step will collect solar power and use this to produce heat in order to reduce environmental impact. The top surface will be made of textured glass to allow the sunlight to reach the incorporated solar cells. Using solar power will also help lessen the cost to run the panels. Solar cells will be implemented into the surface and will generate energy from the sun. This energy will then be stored in a battery to be used when needed.

Powering the Heater using Solar:

In the last decade solar energy solutions have become very common. In the last 10 years, the cost of solar tech has decreased by 70% (Becker, 2019). Dependent on which type of panel, typical efficiency is in the range of 15-22% (Aggarwal, 2020). When designing the Solar Step, it is important to look at the different types of solar panels and choose the best suited to the problem at hand. The three main types are monocrystalline, polycrystalline, and thin film.

Monocrystalline panels are the most expensive due to the precision needed to create them. Despite this drawback, these panels have a good life span and are quite durable. They also provide the most efficient method of energy generation, especially in a small space. This is an important detail considering the small surface area of stairs and Solar Step. These panels are typically around 15-22% efficient (Sendy, 2017).

Polycrystalline panels are formed in a similar way but require less precision. This decreases the cost but produces a lower efficiency, usually in the range of 14-16% (Sendy, 2017). Due to the reduced efficiency, polycrystalline panels require more surface area to produce the same energy generation as monocrystalline. With the Solar Step being built to specific sets of stairs, an increase of surface area is not practical and the decrease in efficiency must be accepted or solved in another way.

Thin Film panels are the most cost-efficient solar panels as they are the easiest to create. These panels can be made more flexible than others and are typically thinner. Other benefits include resistance to high temperatures and more usable in shaded areas than the other panels.

With these advantages comes drawbacks, thin film panels are the least efficient, sitting in the 10-15% range (Sendy, 2017). To combat the lack of efficiency, new methods and materials can be employed to raise the efficiency. If selected for the Solar Step, the material choice of thin film panels would be explored more in depth.

Power generation from the panels will be compared to the requirements of the heating system in order to decide the best possible material. Typical home panel installment panels of 20 ft^2 generate between 17.5 and 42.5 kWh a month. Common panels of this size range from 100-300 watts (Becker, 2019). Ideally, the Solar Step will be exclusively powered off solar power, but this may not be feasible depending on the energy required. To remain as cost and energy efficient as possible, while still getting enough energy to be usable, an additional source such as grid power may be necessary.

Types of heating:

There are a few options when it comes to providing the heat necessary to melt snow, the first being waste heat from solar panels themselves. Solar cells are not 100% efficient, the best ones today are at maximum 30% efficient meaning that the other 70% is reflected or comes in the form of waste heat ("How Much Energy", 2019). If this were to be utilized more research would be conducted to determine exactly how much waste heat is produced by the solar cells and if it would be enough to heat the Solar Step.

Another option is the use of thermoelectric generators (TEGs) which, when a current is passed through, heats one side of the generator and cools the other. In theory, placing the hotter side of the TEG closer to the glass surface of the Solar Step would result in a temperature change on the steps, enough to melt any snow or ice buildup. However, this is not a cost-efficient option, potentially costing upwards of $70,000 per step ("How do Heating Elements Work", 2019).

The most reasonable and favored option for heating the Solar Step is to introduce a heating element/coil. From this there are different coil options, but the most popular is made of nichrome, an alloy made from 80% nickel and 20% chromium ("How do Heating Elements Work, 2019). Nichrome has a high melting point (1400-degree Celsius), doesn't oxidize or expand when heated, and has a reasonable amount of resistance, required to produce heat when a current is passed through it. To further increase the functionality of nichrome, it can be embedded in a ceramic material which makes the heating element more durable during the cycle of cooling and heating, as the Solar Step is constantly cooled from the snow/ice and is reheated by the coil.

Another aspect of the heating element is the diameter, length and layout of the coils themselves. The Solar Step will likely benefit greatest from a grid style layout as opposed to "snaking" the wires in the step (See Fig 1.3 and 1.4). This will allow sunlight to pass through the heating element and reach the solar panels to be converted into energy. Also, it would be wise to include some insulation on the bottoms of the coils to prevent any transfer of heat to the solar panels instead of the Solar Step surface and prevent any unnecessary damage to the solar cells from the increased temperature.

Battery Analysis:

Without proper storage and output of energy, the Solar Step will neither be able to function properly or if functional will lose valuable efficiency. The design and choice of which type of battery the Solar Step will use will be an important aspect of this device. Each potential battery researched must be both efficient, as well as compact due to the size restrictions of the Solar Step. The batteries will be kept outside in cold Canadian winters, therefore, must also be durable in temperatures well below zero degrees Celsius. Three basic types of batteries include lead-acid, lithium ion and saltwater. Research will be taking place on which of these is best suited to the temperature, efficiency and cost requirements for this design.

Engineering analysis:

The purpose of the Solar Step is to provide a safe walking environment for high foot-traffic areas. Given this, the Solar Step will need to withstand the weight of multiple individuals at any moment as well as consistent wear and tear that will lead to degradation of the surface. To account for this, properties of the materials will be analyzed, and weight tolerances will be calculated. Compression strength, tensile strength, elasticity and deformation of the material will be looked at to determine the appropriate choice of materials, thickness and expected longevity.

As the Solar Step will be heating its surface in order to clear it of snow and ice, heat transfer and temperature tolerances will be an important topic. Thermodynamic analysis will be conducted to see how the materials chosen transfer heat from the point of generation to the surface and how much heat is lost in the transfer. How the materials behave under high and low temperatures will be observed to ensure the system works under the conditions it will be subjected to, within a reasonable threshold.

In order to power the Solar Step, energy generation from solar power will be used. The device will absorb solar radiation, transfer it to energy that will be stored until the use of the heating element is required. This will involve circuit and power analysis, as well as studying the effectiveness of storage devices, and the efficiency of panels, and the efficiency of the heating coils.

Finally, the goal of this project is to find the most economical way to produce this product. Cost of materials will be an important factor in this design. Long-term economic analysis will also be conducted to understand what reductions in energy cost and labor costs would be required to validate an installation of this technology.

Design obstacles:

As with any idea, the Solar Step comes with many obstacles to overcome. The following are problems that will be tackled during the project; Is there enough sunlight during the winter to power the heating system? Will the panels need to be cleaned frequently and will this affect the efficiency? How will the heating elements be arranged to successfully melt snow/ice but not inhibit the production of solar energy?

Additional challenges are provided while trying to maintain traction for walking. The top surface of the panel should be texture to allow for safety of users. Some panel designs for solar roadways use a hexagonal shape to help achieve traction. This could also be designed to help with melt water drainage, so it does not pool on top of the panel after melting.

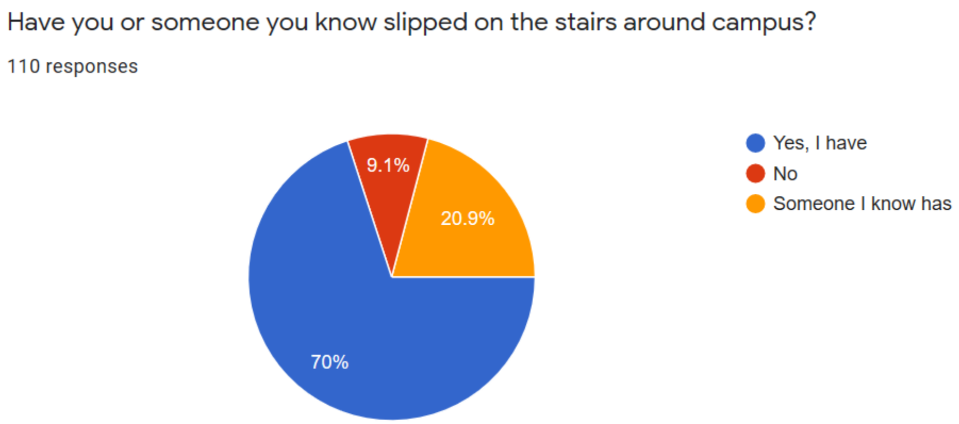
These are just some of the issues that must be dealt with. Although the answers and solutions are not yet clear, by the end of the project period, solutions will be provided to make the Solar Step effective in clearing snow, while remaining practical.

Diagrams:

Fig 1.1 Timeline of proposed project

Week	Presentation	Written report	Assignment/goal
1 (Feb. 3-10)	Completed	Proposal due Feb. 7th	• Finish proposal • Rough sketch of design
2 (Feb. 10-17)			• Decide on materials to be used • Meet with Paul
3 (Feb. 17-24)			• Drawings of stairs (include solar panels, coils, glass and rubber on bottom of mat) • Engineering analysis of amount of sunlight and power output
4 (Feb. 24- Mar. 2)			• Cost analysis (of materials, energy) • Prepare for progress report
5 (Mar. 2 – Mar 9)	Progress report on 3rd	Progress report on 6th	• Start solving obstacles that were outlined in first proposal
6 (Mar. 9-16)			• Prepare for project update
7 (Mar. 16-23)	Project update on 17th	WEB SUBMISSION	• Complete website
8 (Mar. 23-30)	Final report on 24th	Final report on 27th	

Fig 1.2 Student survey results



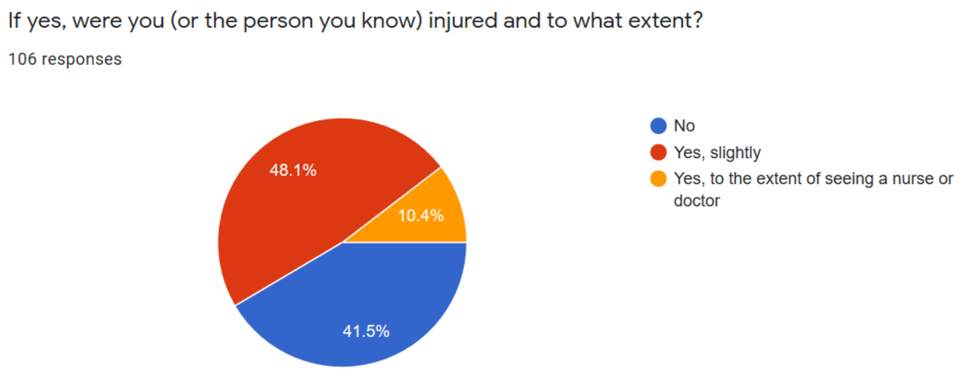


Fig 1.3 Grid Style Coil Layout

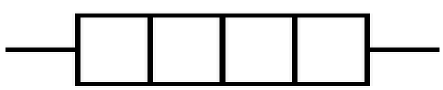
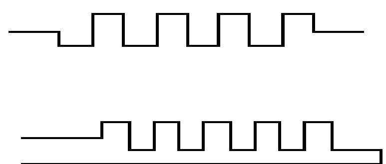


Fig 1.4 Snaking Style Coil Layout



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