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Board 100: Hot Wheels: Heated-Seat Wheelchair

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Heated Seat Warmers through Rotational Energy on a Wheelchair

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Abstract
There has always been a need to innovate better medical equipment in order to improve lives, especially those disabled. Our team chose to innovate upon wheelchairs through the means of renewable energy, and designed a device called "Hot Wheels." Our product harnesses rotational energy from the wheelchair's wheels and converts it into thermal energy to power heating pads below the seat, and on the back of the wheelchair. The energy to do so will come from the consumer turning the wheel, utilizing mechanical energy. We attached gear and washer to a generator that sits inside a mounting mechanism on a rod of the wheelchair, all connecting to a Sparkfun circuit and then to a heating pad on the seat. With constant movement, we were able to produce heat from the heating pad. We recorded the amount of voltage produced over time through the Arduino serial plotter.

Introduction
Homelessness is a pressing public health and social issue, as two percent of the world's population experiences it equating to about one hundred and fifty million people worldwide. Moreover, about forty percent of those who are homeless are also disabled. Cold climates are home to a large portion of the homeless, with New York, Oregon, Washington, and Massachusetts having some of the highest percentages in the United States. Heated wheelchairs can provide a significant improvement in comfort and quality of life for people with limited mobility, especially during the colder months. Some wheelchair manufacturers offer heated wheelchairs as an option, while others specialize in producing custom or modified wheelchairs with heating elements. Our group wondered how we could possibly improve this medical device for those who are in need of it. We knew that the best way to generate electricity on a wheelchair is through the rotation of the wheels. The idea of using the wheelchair's rotational energy to power heated seat heaters involves converting the mechanical energy produced by the rotating wheels into electrical energy, which can then be used to power the seat heaters. One approach to achieving this could be through the use of a generator that is connected to the wheels of the wheelchair. As the wheels spin, the generator converts the mechanical energy into electricity, which can then be stored in a battery or used directly to power the seat heaters.

In the late sixteenth century the more conventional looking wheelchair was adapted with a self-propelled chair being manufactured in 1655 [1]. The wheelchair then began to have a larger purpose for medical needs. Slowly wheelchairs began being electrically powered. Similar to how we wanted to approach our project, we examined a report about a group of researchers that were able to generate electricity using the chain and wheels on bicycles. The group created a generator at the base of the gears on the bicycle to store the energy that was being generated [2]. We adopted a system similar to this but used our circuit to convert that energy into thermal energy.

With our model, we used an actual wheelchair to best resemble that our concept works. Having the actual wheelchair allowed us to properly put our device to use. The project was split into two main processes: hardware and software. The hardware involved determining how to best place our generator and gears on the wheels to best harness energy. On the other hand, the software involved using our Sparkfun circuit to translate the rotational energy to thermal energy.

This work was carried out within the framework of an innovative teaching approach used in a newly designed eighty-credit engineering course for first-year engineering students, the "cornerstone of engineering." The undergraduate students did this work. This approach is very effective and well suited to educate students. Rather than just studying for exams to gain good grades, these skill- and knowledge-integrated approaches help highly motivated students to interact with other students and faculties from various institutions and take further strides towards real world issues.

Methods and Approach

To mount our device on our wheelchair, we used 3D printed and laser cut parts. In order to house our generator at the bottom of the chair we 3D printed a cylinder casing that would be on the wheelchair and the generator would be attached to the casing. We decided to build our design around this part on the wheelchair as there was already a screwhole that we could use to properly secure our casing and generator. Additionally, we designed screw holes in our Solidworks drawing for the generator as our generator already had holes going through it. With this we were able to secure the generator in the casing.

For the generator, we laser cut a small gear. This gear would be attached to the axle on the generator and be able to spin as the spokes front the wheel hit the gear. In addition to the gear, we needed to print a small washer to place below the gear so the screws would not block and interfere with the gear. Regarding our Sparkfun circuit, we ordered heating pads from the Sparkfun website. These heating pads would easily work with our Redboard. After talking to an engineering tutor, we were informed that we would also need to incorporate a MOSFET into our circuit since the current and voltage of the heating pad was larger than what the Redboard could maintain. The MOSFET is able to amplify the voltage of the Redboard which would make our heating pads work efficiently.

Design Details

When we got our wheelchair, it was obvious that the design we originally had in mind would not be possible. It relied on the assumption that the back wheels of the wheelchair had an accessible axle, but that was not the case. In fact, the wheels spun on bearings that were built into the wheels themselves. The metal rod the bearings were mounted on did not rotate at all, which left us back at the drawing board.

After a deep inspection of the area around the wheels, we removed the rubber stopper on one of the rods in the framework and discovered a screw hole. We knew we would be dealing with a lot of torque going towards our design, and it would have to deal with a lot of stress. Therefore, we decided this screw hole (Figure 1a) could be very useful as a firm way of attaching our motor to the wheelchair. We also realized that the sparkfun motor fit almost perfectly in between the rod with the screw hole and the wheel itself, so we aimed to attach the motor there to maximize security and torque. We also found two screw holes in the sparkfun motor itself (Figure 1b), and decided this would be a solid way of attaching the motor to the piece which would attach to the wheelchair.

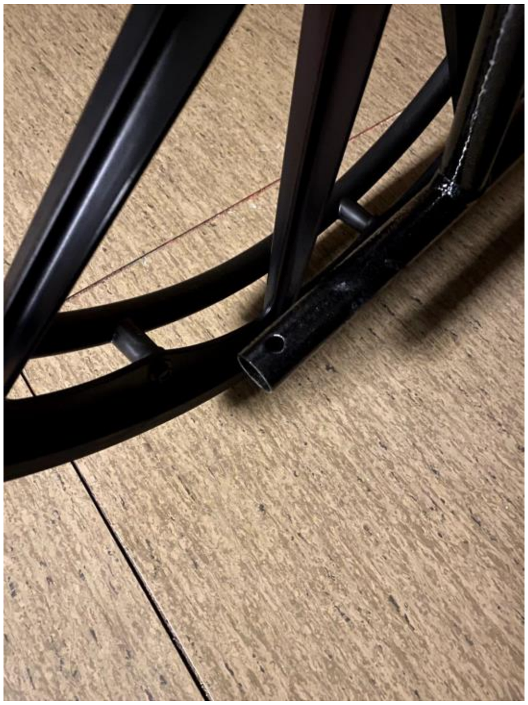

Figure 1a: Screw hole

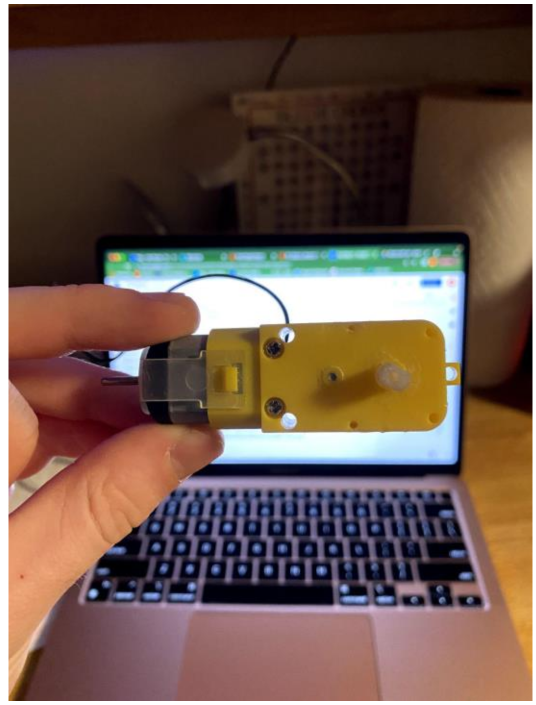

Figure 1b: Sparkfun motor

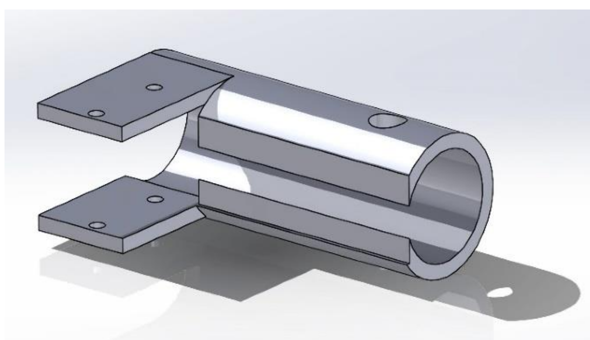

Figure 2: 3D drawing

Next, we had to design the piece that would attach to the wheelchair's frame and the Sparkfun motor. For this, we used solid works, as we planned on 3D printing the piece. We were working with about 12 cm of length on the rod, and the diameter of the inside of the part had to be just about 2.2 cm to fit on the rod. We tried to find the best balance of strength and freedom of mobility, as we wanted the piece to be strong enough not to break, but needed to allow for the full unrestricted rotation of the motor. With these things in mind, we decided on a thickness of 0.3 cm. The goal was to have the motor screw in directly adjacent to the rod, so we extended two flat parts far enough away from the rod to fit the motor. However, the height of the motor was less than the height of the printed part, so we had to have these flat parts as high up on the cylinder as possible to ensure the freedom of any gears we planned on using on the top of the motor. The only thing remaining was to add the screw holes. With that, our 3D part's design was complete (Figure 2).

Now we had to design a gear to attach to the Sparkfun motor, which would be spun by the wheel. For this, we used Autocad with the intention of laser cutting the design. The gear had to be large enough to be spun as much as possible, while also not being so large that it would get stuck in the wheel. We also had to choose the amount of teeth very carefully - too few teeth would result in the gear ending up in a position where it wouldn't be spun by the wheelchair's wheel, and too many teeth could result in the outer edge of the tooth being hit by the spoke of the wheel, which could break the entire design. After some experimentation, we decided on six teeth, with an outer radius of 2 cm and an inner radius of 1.5 cm. We also had to measure the shape of the spinning peg on the Sparkfun motor very carefully, to ensure that any spinning of the gear would result in spinning of the motor as well. The dimensions we got for the peg were 0.4 by 0.55 cm. Finally, since the flat part of the 3D printed piece went within the radius of the gear, the gear would hit it and not be able to spin. To avoid this, we designed a washer (Figure 2b) with radius 0.6 cm to go in between the motor and the gear, raising the gear high enough to avoid any other part of the design. We decided to cut with acrylic because of its durability and sleek aesthetic. With our elements designed, we printed the piece (Figure 3b), cut the gear (Figure 3a) and washer (Figure 3c).

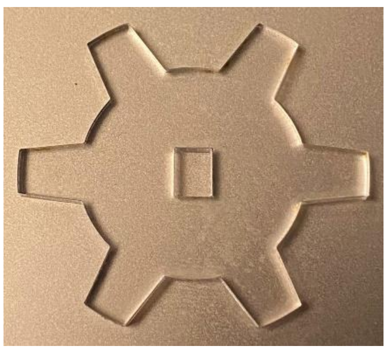

Figure 3a: Gear

Figure 3b: 3D printed part

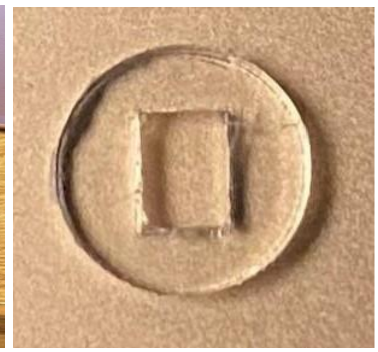

Figure 3c: Washer

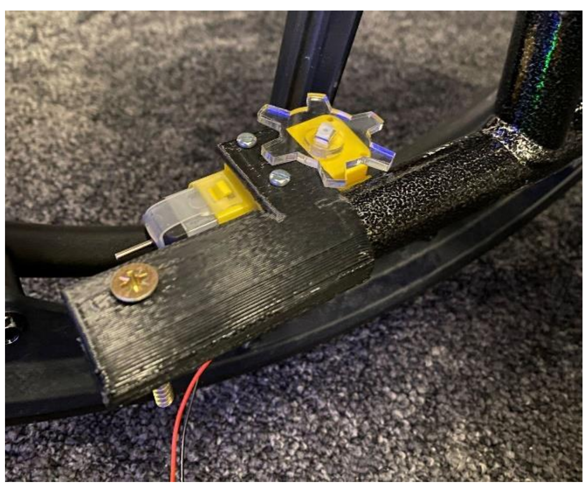

Figure 4: Sparkfun Motor Implementation

With our physical elements now created, all we had to do was put them together. We used 1" long ⅝" wide screws for the Sparkfun holes, and a larger screw for the larger hole. They fit well enough in the printed piece those washers to hold the screws in place were unnecessary. We then super glued the washer and gear to the Sparkfun motor. With that, the physical aspects of our design were complete and assembled (Figure 4).

Once we had those elements in place, we moved on to the electrical system. First we wanted to figure out how and where to attach the heating pad. We decided to use Velcro so the pad would be easily detachable, and we placed it in the middle of the seat to maximize the spread of the heat we generated. Once we had that secure, we had to learn how to power the heating pad with the Sparkfun kit. This proved to be more challenging than anticipated, and it turned out that we needed a MOSFET to get sufficient power to the pad. Since the maximum voltage of the Sparkfun is 5V, and the heating pad operated at a higher voltage, we had to run the wires through the MOSFET to amplify the voltage output. With the addition of the MOSFET, our system was complete. We placed the Sparkfun conveniently in the back pocket of the wheelchair then added extension wires between the motor, Sparkfun, and heating pad. After taping those wires to the frame of the wheelchair for cable management, our final prototype of the design was complete (Figures 5a and 5b).

Figure 5a: Final design –Top view

Figure 5b: Final design - Circuit

Results and Discussion

The following graph (Figure a) shows a plot of voltage (V) vs. time (Sparkfun refresh rate at 9600 baud) [3-5]. The blue line represents the voltage we were generating, the green line represents the target voltage at 5v, and the red line sits at 1v for reference. We started moving relatively slowly in the wheelchair as we had had some problems with the teeth of the gear hitting the wheel at the wrong angle and sped up over time.

As you can see, the motor fails to generate a continuous smooth voltage output. This is because the spokes of the wheelchair's wheel were too far apart to be constantly spinning the gear. The result is a spike of voltage whenever the wheel spins the gear on the motor. Moving slowly, this would not effectively power the heating pad, as we would need about five volts of constant power to heat the pad up over a couple minutes. However, at about 180 refreshes, we sped up fast enough to constantly generate energy. This was going at a very reasonable speed, and although we failed to reach the target voltage of 5V, this speed would heat up the pad over a longer period of time. At its best, the generator was averaging around 3V. This would be enough to mildly heat the pad, but not as much as we had been hoping for. Given the results from our tests, we were unable to reach our goal of generating 5V. While we failed to achieve that goal, we were able to generate a consistent 3V while moving at a normal pace. This was not enough power to make a very noticeable difference in the feeling of the heating pad, but we were still able to generate a noticeable amount of heat. That being said, there are a number of things we could change to improve our design. It is notable to mention that the exact amount of heat generated was not measured, as a scope or tool which could perform this task was inaccessible. This said the pad did become warm to the touch.

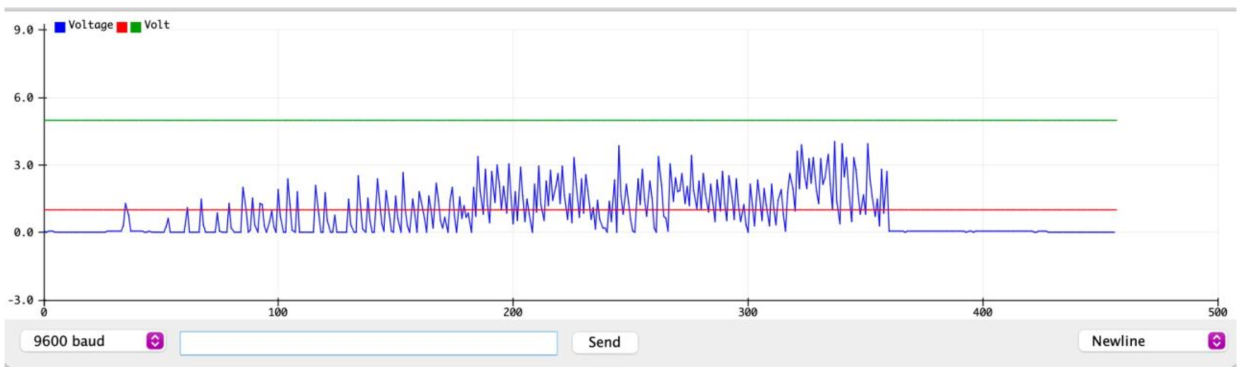

Figure 6: plot of voltage (V) vs. time

We prioritized sturdiness and strength over efficiency, knowing that we would be dealing with a substantial amount of torque. Our initial goal was to have a functional design to prove our concept, and then be able to expand on the idea to improve the efficiency and achieve our desired voltage. The gear system that we had in place lacked a constant rotation, which caused a lack of constant voltage generation, which is essential to powering the heating pad since they require a constant five volts of energy. If we were to improve the efficiency of our design, we would likely change the location of the motor itself so that it would be closer to the center of the wheel. This would mean the spokes of the wheel would be spinning the gear of the motor at a more constant rate, generating a more constant flow of power. We would also implement a gear ratio to increase the rpm of the motor while moving the same speed in the wheelchair.

Another large factor we were dealing with was the quality of our materials. We were using the materials at our disposal - the Sparkfun motor, laser cut acrylic, and 3D printed plastic. These materials, while they did succeed in proving our concept, resulted in a weak and inefficient prototype. In fact, both the acrylic laser cut gear and the 3D printed part snapped on separate occasions during testing. In order to successfully market this idea as a product, we would have to make these parts out of stronger materials, such as metal. In addition to those parts, the Sparkfun motor is not very efficient, and would need to be upgraded to a significantly more efficient generator.

Conclusion

We conclude that the basis of this idea and technology could successfully be applied to wheelchairs to generate thermal energy. However, there are design flaws that need to be fixed. Currently, our main issues are that the quantity of energy harnessed from the wheels is not sufficient for the user to feel an amount of heat that would truly help battle cold weather, and the user must be almost constantly moving the wheels. For the heating pad to be hot it requires 5V and we produced 3V maximum. We could implement a battery so that no energy harnessed goes to waste, and the heat could be potentially turned off and on, or even be set to different heat levels, like seat warmers are in a car. Additionally, we could add a whole gear system involving multiple gears to help control torque and channel more rotational energy. Most of our design goals were met except for generating the amount of energy we hoped for as mentioned above, but also for the wheelchair to be waterproof. For the system to be profitable and put on the market, it must be waterproof. Any sort of precipitation could disrupt or damage the system or hurt the user. With more time, better resources, and a bigger budget, we believe this could easily be done by having the technology built inside the chair and/or design casing to shelter it. Aesthetics would improve with this as well. Our concept, fortunately, proved to work. We believe if we were able to build a wheelchair from scratch to work with our idea, like making the spokes closer together to hit the gear more often, we could have pulled off all our goals.

Although there are still points of improvement for the Hot Wheel, but we have gained a multitude of valuable experiences that have shaped our view of engineering and educated us on the importance of persistence and collaboration. The systematic approach of our project provided us with a large array of skills from research, design, and construction as well as testing and technical writing. Additionally, collaboration was extremely important to this project as we learned how to communicate with different people and engineers as well as discovered how to spend our time the most effectively. The paper also highlights how student projects can be used for innovative solutions to real-world problems and how to prepare engineers for future needs.

Reference

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[5] T. A. Team, "Using the serial Plotter tool: Arduino documentation," *Arduino Documentation | Arduino Documentation*. [Online]. Available: https://docs.arduino.cc/software/ide-v2/tutorials/ide-v2-serial-plotter. [Accessed: 28-Apr-2022].

Appendix 1 - Data Collection Through Arduino Serial Plotter

```
#include <LiquidCrystal.h>
// Constants
int VOLTAGE_PIN = A0;
int Acontrol_variable = 5; int Bcontrol_variable = 3;
// Global variables
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup() {
    // Initialize the annoying LCD and clear it
    lcd.begin(16, 2);
    lcd.clear();
    // Initialize the serial monitor
    Serial.begin(9600);
    }

void loop() {

    int sensorValue; float voltage;
    // Read the analog value from A0
    sensorValue = analogRead(VOLTAGE_PIN);
    // Convert the analog value to a voltage
    voltage = ((float)sensorValue * 5.0) / 1023;
    // Display the voltage on the LCD lcd.setCursor(0, 0); lcd.print
    lcd.print(" V");
    // Wait 200 ms before taking another reading
    delay(200);
    // Serial controls Serial.print("Voltage:"); Serial.print(voltag
    Serial.print("1 Volt:"); Serial.println(Acontrol_variable);
    }
```