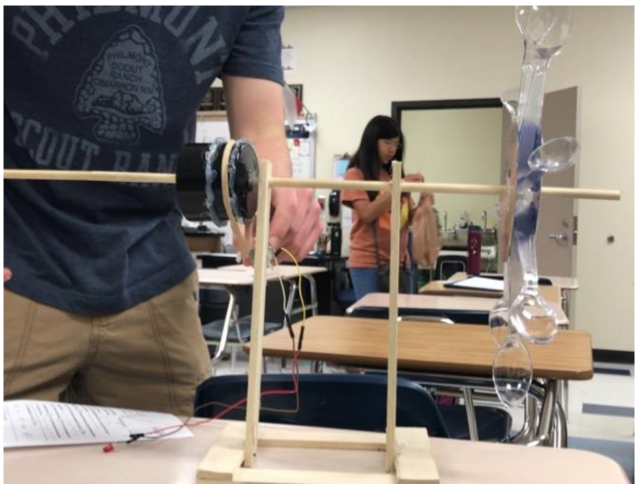

HYDRAULIC GENERATOR

"The Waterwheel of Doom"

ABSTRACT

A hydraulic generator converts the mechanical energy of falling water into electrical energy though the use of a generator. These designs utilize the physical laws of magnetism and rotational mechanics and are used to generate power across the globe.

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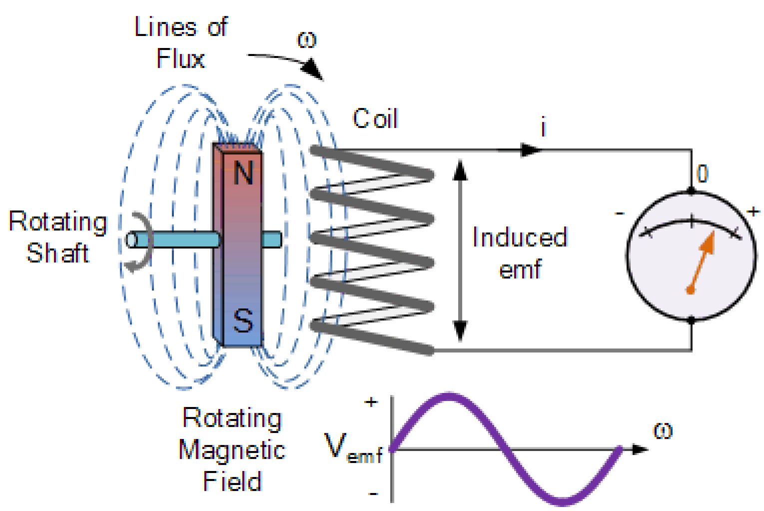
Physics II AP

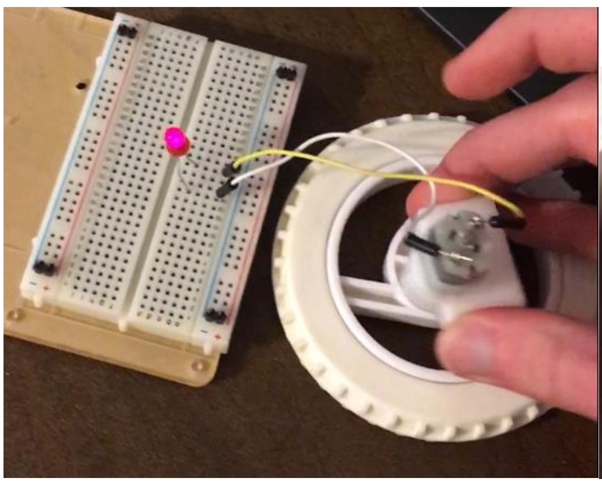
Hydroelectricity is electricity generated by using the natural movement of water to rotate a generator. Our group was inspired to choose this project because of the modern push to adopt more ecological methods of generating power, hydroelectricity. These systems utilize many physical properties of magnetism, electricity, and general dynamics. By working on this project, we developed a deeper understanding and appreciation for this technology.

The system is comprised of two subsystems working together: the generator and the waterwheel. The generator consists of all the electrical components, such as the electric generator and the power collection system. The electric generator itself has two parts: the stator and the rotor. The stator is the frame of the electric generator and contains a series of wire coils. Rotating inside the stator is the rotor, which contains several large magnets. As the rotor spins, the magnets produce a changing electric field in the coils. This change in field produces magnetic flux, and this flux creates a voltage in the wires. This relationship is explained by using Faraday's Law, $emf = -\mathrm{N}\frac{\Delta\Phi}{\Delta t}$. When simplifies to reflect the constant nature of the coil, magnetic field, and rotation, the power output oscillates based on the equation $\varepsilon = \varepsilon_0 \sin(\omega t)$. This means that a spinning electric generator produces alternating current. The next component of the generator is a way to harness the



mechanical energy of water to spin the rotor. This is typically done with a waterwheel, which is a large wheel covered in blades that the water hits when it falls. This turns a drive shaft, and this shaft turns the rotors. To increase the mechanical energy of the water, generators are placed in areas with very fast flowing or falling water.

We started our project by creating the generator. Instead of a generator, we used a small electric motor. These are identical, but a motor is used to input electrical energy and output mechanical energy. When mechanical energy is input instead, they will function in reverse and create electricity in the process outlined above. When tested using a gearbox wired to a small LED, this was able to light the bulb. This test system was simplified by soldering the wires together and removing the motor from the gearbox.

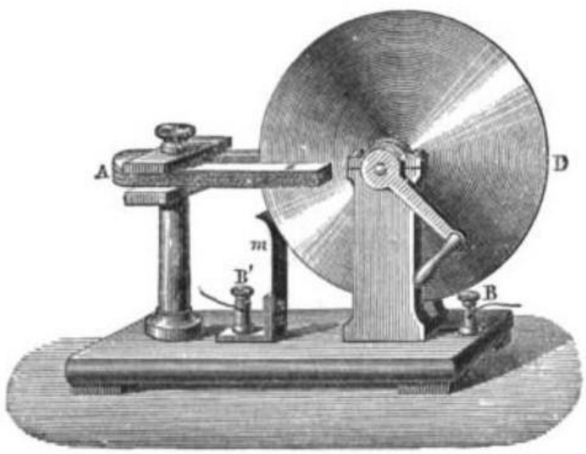


Next, our group developed the wheel of the waterwheel. The structure of the wheel was made from CD discs. We chose these because they are durable, round, and have a hole in the middle that could accommodate a central axle to use as a drive shaft. Attached to the discs were several spoons distributed radially, all with concavity the same way. The whole structure is held together by a very strong glue. It’s called hot glue cause its hot when it is applied. Hot! The spoons form the blades of the waterwheel and allowed the water to push the wheel and rotate it.

The spoons were all the same concavity to make sure that the wheel only spun one way. Because the LED we were trying to power only works with the cathode and anode aligned the correct way across the circuit, spinning the wheel the wrong direction would generate electricity but not light the bulb. Once the waterwheel was complete, we had to find a way to transfer the rotational energy from the wheel to the generator. Direct drive would spin the generator, but not fast enough to generate the voltage required to light the bulb. We needed to create an indirect drive train with a low mechanical advantage. This would convert the torque on the waterwheel to higher rotational velocity, which was needed with such a low resistance generator. To create this, we built an indirect drive train with a belt system on a low gear ratio. A gear ratio is a ratio to the radius of two gears used in a belt system. A larger wheel driving a smaller one has a low gear ratio and creates a low mechanical advantage. This allows the rotor of our generator to spin faster than the waterwheel and makes our power generation easier to accomplish with water.

Attaching this gear system to our generator was successful in lighting our bulb when spun fast enough. Some problems we had with our design was that we could never have water strike the blades of the wheel fast enough to light the bul. This is likely indicative that our step down on the drive shaft was insufficient. Another step, or larger difference in gear sizes, would have resolved this issue. Another problem is our reliance on a friction belt. The nature of a hydroelectric generator brings it in close contact wit water, and water decreased the friction felt between the belt and gears. This severely limited our energy production. To resolve this, we needed to keep the water from reaching the belt. A simple divider was able to accomplish this. At the end of our project, spinning the wheel by hand was able to generate approximately 0.2 A and 1.5 V. I’m not actually smart enough to use a multimeter and didn’t know what all the settings meant but that’s what it read, and my dad was helping me so that’s probably pretty close.

Electric generators have been in use for nearly two centuries. The first electric generator was built by Michael Faraday in 1832. These generators created direct current electricity and were highly inefficient. The alternating current generator would not be developed until 1882, when they were designed by J.E.H. Gordon. Today hydraulic generators are used across the world in hydroelectric dams. These were first applied in the industrial revolution to power factories. William Armstrong developed the first hydroelectric system when he used a waterwheel to power a single light. Many notable dams, such as the Hoover Dam, were designed



to generate hydroelectricity. The largest hydroelectric dam in the world is China's Three Gorges Dam, generating 22,500 MW. In the United States there are over 2,000 hydroelectric plants that supply 6.4% of the nation's electricity. Another common use of electric generators is in cars. The alternator of a car is used to keep the battery of the car charged. These generators use the mechanical energy of the engine to turn the rotor and generate power. The future of hydroelectric power sees it becoming one of the most important methods to generate power as fossil fuels are phased out in favor of more ecologically friendly options. Most regions do not fully utilize their potential to generate hydroelectric energy, with many regions only reaching 5% of their potential. As methods to generate power become cheaper and easy to develop, hydroelectric power will see much mote use in the future.

The use of hydroelectric power is on the forefront of the battle to slow global warming and provide clean energy. Because of physical concepts such as Faraday's law and the rules of gear systems, electricity can be generated from nothing more than the natural movement of water. Building a hydraulic generator helped me to understand these properties and prepare for the Physics II AP test, even though I'm not taking it.

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