Honors University Physics II Project:
Kelvin Water Dropper

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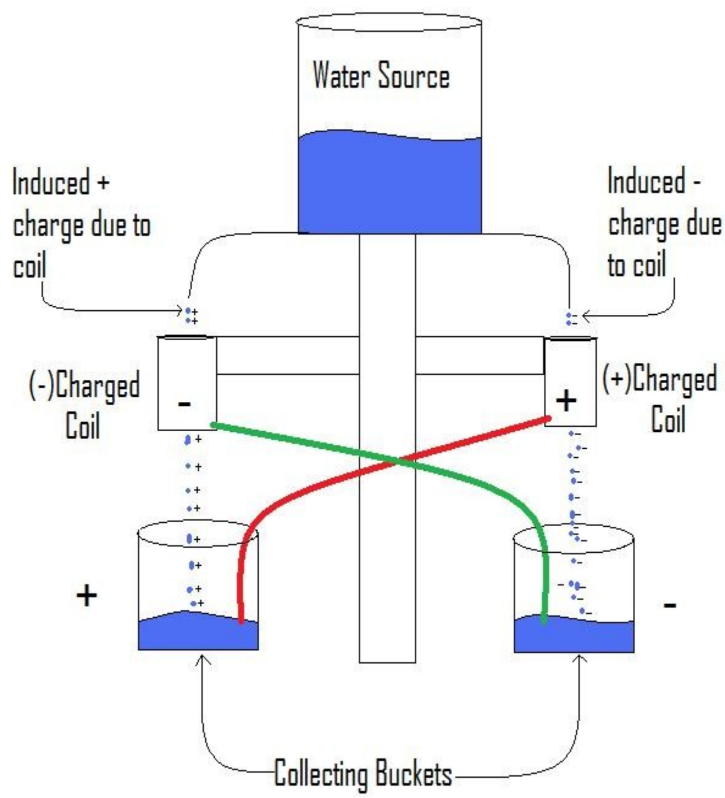
Ever since the Renaissance, the great minds of Western society have been tried to explain the natural world with science. During the nineteenth century, scientists such as Michael Faraday, Carl Gauss, and James Maxwell dedicated their lives to the study of electrostatic and magnetic phenomena. One scientist, William Thomson also known as Lord Kelvin, studied the electrostatics in relation to a variety of substances, one of which was water . During the course of his research, Lord Kelvin developed a device that could separate the small amount of charge that naturally occurs in water due to dissolved salts and acids. His device is known as the Kelvin water dropper or Lord Kelvin's Thunderstorm ("William Thomson, 1st Baron Kelvin").

The Kelvin water dropper is a simple device which consists of a large water reservoir, two metal conducting coils, two collecting buckets, two tubes, and two wires. To make the device, the large water reservoir is placed above everything else. Then, two tubes come out of the bottom of the reservoir. Next, each tube directs a stream of falling water through a conducting coil. After that, the water falls and lands in the collecting buckets. One wire will run from the bucket on the left to the coil on the right. The other wire is set up in a similar cross pattern (see fig. 1). When assembling the apparatus, the support structure should be made out of a nonconducting material such as PVC to prevent the system from discharging. Additionally, the collecting buckets should be made of plastic to prevent any undesirable discharging (Beaty).

The physics of the Kelvin water dropper is fairly simple. One of the basic premises of the dropper is that the water in the reservoir contains small amounts of charge in the form of dissolved salts and acids (Beaty). To help the system work, a teaspoon or two of table salt can be added to "load" the system. As the water falls into the buckets, a small amount of charge will randomly build up in one of the buckets (Gal, Kelvin and Maclean 484). For sake of example, call this a positive charge. This positive charge then distributes itself throughout the water in the bucket and the surface area of the coil above the opposite bucket via the wire. The positive charge on the coil induces a negative charge in the water falling from tube above it. The negatively charged water then falls into the bucket below. Next, the negative charge distributes itself over the coil above the positively charged bucket. The negative charge then induces a positive charge in the stream of water falling into the positive bucket. As a result, the system charges exponentially. It starts charging slowly and builds rapidly like a snowball rolling down a hill (Beaty).



(Figure 1)

As the system charges, several interesting phenomena can be observed. When the buckets contain enough charge, the falling droplets begin to spray everywhere instead of falling into the buckets. This effect is due to the electrostatic repulsion of particles with the same charge. Since the falling droplets have the same charge as the water in the buckets, the droplets are repelled. Another amazing effect occurs around the charged coils. If one looks from below at the water coming out of the coils, one will observe that some droplets appear to fly upward and spin around the coils. This effect is due to the fact that the coil attracts the oppositely charged water droplets as the droplets pass through the coil (Beaty).

To discharge the system, one simply needs to attach an additional wire to each bucket and bring those two wires close enough for the charge to arc across the gap. This technique can be used to determine the total potential of the system. Simply measure the farthest discharge distance between the two wires. Then multiply that distance by the value for the dielectric breakdown of air which is 3,000,000 V/m (Stewart 129). In this experiment, a maximum arcing distance of 5mm was observed. Multiplying 5mm by 3,000,000V/m gives a total potential of 15,000V!

In the end, the Kelvin water dropper proves to be an effective way to separate electrostatic charge from falling water. Additionally, this device demonstrates several key principles of electrostatics, including: like repels like and opposites attract.

Works Cited

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2. Gal, Alexander. Lord Kelvin and Magnus Maclean. “Electrifications of Air, of Vapour of Water and of Other Gases.” *Proceedings of the Royal Society of London.* The Royal Society. Vol 61, (1897), pp. 483-485)
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4. “William Thomson, 1st Baron Kelvin” *Wikipedia: The Free Encyclopedia*. Wikimedia Foundation. March 15, 2010. <http://en.wikipedia.org/wiki/William_Thomson,_1st_Baron_Kelvin>