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Honors Project

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Lab Section L1

# The Shocking Truth Behind Van de Graff Generators

Countless children and adults alike have been amazed by the "shiny orb" at the science fair that shocks them when they get close to it and makes their hair stand on end when they touch it for a prolonged period of time. For my honors project I intend to shed light on the physics behind the Van de Graaff Generator that I built and provide commentary on my experience while constructing it.  In order to make my explanation on the physics easier, I have included a drawing of the Van de Graaff Generator kit below, taken from a 2009 Honors Project by Bryant Virden with permission of Dr. John Stewart (Figure 1).

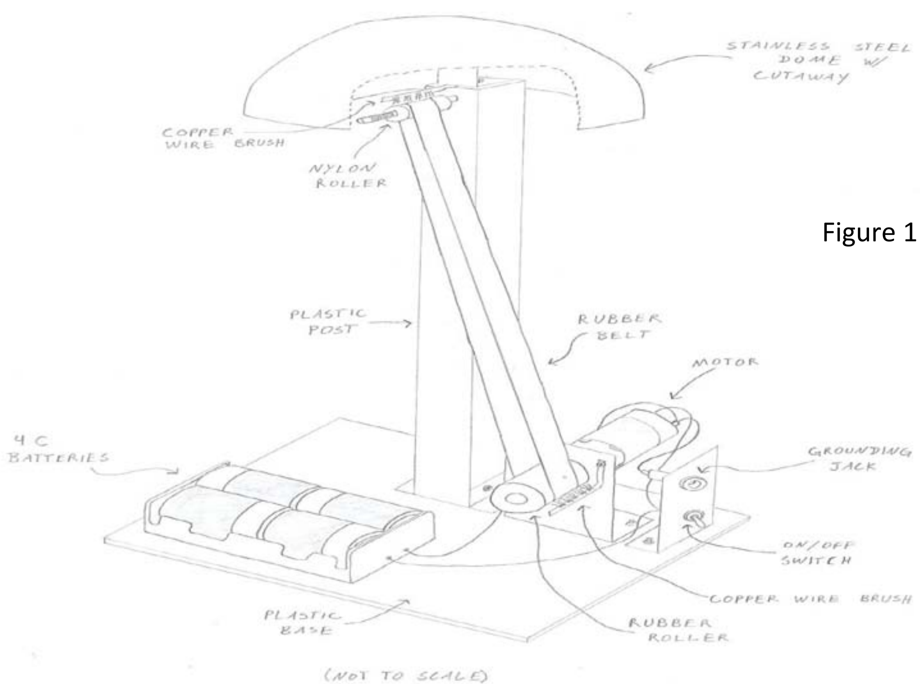


Figure 1

# Explanation

In the late 1920's a MIT professor by the name of Robert J. Van de Graaff invented a machine that was capable of producing millions of volts of static electricity in a very short period of time (History of the Van de Graaff Generator). This machine that came to bear his name was simple in concept and design, but extremely useful in the early studies of atom smashing nuclear physics (Zavisa). Van de Graaff's generator focused on using known elements of the physics realm such as the triboelectric series and the behavior of opposite and like charges.

To start, an understanding of the triboelectric series is crucial to comprehend how the Van de Graff Generator works. The triboelectric series is a list of different materials tendencies to give or take electrons when they are rubbed against another material (Zavisa). If the object lies towards the positive end of the spectrum it is more likely to take electrons from the object it is rubbed against. The inverse goes for the negative end as well. Therefore, in my Van de Graaff Generator; which has a rubber belt, a rubber bottom roller, and a nylon roller on the top, the nylon roller gives up electrons to the rubber belt as they rub against each other due to their positions on the triboelectric series (see Figure 2). This causes the nylon roller to develop a positive charge and it causes the belt as it leaves the top roller to have a negative net charge.

Figure 2 –from www.ecd.com


Now that a positive net charge has been developed on the top roller we can examine the transfer of charges that occurs, allowing us to develop a net charge on the conducting sphere at the top of the generator. Above the top roller and belt there is a copper comb that has numerous thin wires hanging down about $1/16^{th}$ of an inch away from the belt. The comb is in physical contact with a conducting bracket that is also connected to the conducting sphere located at the top.  As the positive charge begins to increase on the top roller the negative charges in the collection of conducting materials (comb, bracket, and sphere) begin to move towards the ends of the comb trying to get as close to the positive nylon roller as possible. The negative charges try to jump to the roller and instead coat the belt which takes them away down towards the bottom roller. Nearby air molecules also contribute to the concentration of negative charges on the belt through a process called corona discharge. In corona discharge the electrons in the nearby air molecules are stripped from their atoms and the atoms become plasma while the electrons are attracted to the positive roller and coat the belt with more negative charges (Zavisa). The negative rubber belt and subsequently negative rubber roller (they are made of the same material so the charge will try and spread out as much as it can, therefore transferring some charge to the rubber roller) will act similarly to the nylon roller and start having the negative charges from the belt jump to the copper comb at the bottom of the generator. They jump from the belt to the comb because as the roller gets negatively charged the negative charges that keep being moved down from the belt will be repelled from the roller and jump to the copper comb. These interactions occur rapidly and often as the belt spins, thus quickly taking the negative charges away from the conducting sphere on the top leaving the positive charges to spread out over the sphere (Moore). When the hand of a willing (or sometimes unaware) person comes close to the generator they will experience a dielectric breakdown of the air (spark) and become a giant donator of electrons to the conducting sphere.

## Construction

I built my Van de Graaff Generator using a kit I purchased from Chaney Electronics. It contained a base and a tower to support the generator and all the necessary parts to build the generator itself: a motor attached to a power switch, a battery pack that holds 4C batteries (power supply), a rubber roller, a nylon roller, a rubber belt, two copper combs, a metal conducting dome, and all the brackets and screws needed to put it together. The first time I turned it on and attempted to create a spark between the top dome and my finger nothing happened. I thought that because it was a smaller generator compared to the ones I have used in lab that I needed to give it more time to develop a charge at the top. After letting it run for five consecutive minutes I tried to touch it again: nothing. My next thought was that the copper wire that was supposed to interact with the belt at the top of the belt was too far away from the belt. I pushed it down closer to the belt and gave it another attempt. Still nothing. At this point I was struggling to see why it wasn't working like I thought it would. As a last ditch effort I borrowed, without asking, my sister's hair dryer. Before I turned on the generator I used the hair dryer to blow hot air over every inch of the apparatus hoping that it would battle the humidity that I assumed was prohibiting the charges from being transferred. This time when I flipped the switch, the Van de Graaff Generator came to life and worked perfectly.

# References


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