THE HANDHELD VAN DE GRAFF GENERATOR

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ABSTRACT

The Van de Graaff generator is an electrostatic generator that creates extremely high electric potentials by accumulating electric charge on a hollow metal sphere on top of an insulated column through a moving belt. It generates low-current direct current power with a very high voltage (Katz, n.d.). As seen in Figure 1, a Van de Graaff generator attracts electrons, which are then moved along a belt and stored on the large sphere. These electrons oppose one another and spread out across the sphere's surface, attempting to get as far away from each other as possible, causing this "zap" from the wand to the sphere.The generator was created by Van de Graaff to provide the high energy required by early particle accelerators (Katz, n.d.). Atom smashers were named after the accelerators that accelerated subatomic particles to extremely high speeds before "smashing" them into the target atoms. Other subatomic particles and high-energy radiation, such as X-rays, were formed as a result of the collisions. Particle and nuclear physics are built on the capacity to produce these high-energy collisions (Zavisa, 2020).

INTRODUCTION

History

When Robert J. Van de Graaff returned to the United States from Oxford in 1929, he became a National Research Fellow at Princeton University's Palmer Laboratory. The movement of electromagnetic charges was discovered as a feasible mechanism for producing extremely high voltage in the 1930s. Nuclear physicists imagined systems that transport charged particles as liquid, rather than solid, such as a belt. (IEEE Xplore Full-text PDF, n.d.)

Van de Graaff understood that voltage could be made by running a belt between two pulleys, one at ground and the other in an isolated environment, both supported by insulators. However, the challenge was moving charges off of the belt that was carrying the charge. (IEEE Xplore Full-text PDF, n.d.) In the process of charging, the sphere tries to push the positive charges away when trying to bring more charges up. Van de Graaff came up with the idea of employing a re-entrance mechanism, in which the belt enters the sphere from the inside. The sphere mechanism is a critical component because once inside the sphere, the charges are naturally pulled to it, attempting to reach the sphere's exterior surface. Charges are moved from any place inside the sphere to the sphere's external surface by a force. It was highly efficient and effective to remove the charges from the belt by bringing the pulley within the sphere, which is the charge-collector. (IEEE Xplore Full-text PDF, n.d.)

The Van de Graaff generator is the last in a long series of machines that date back to the earliest times in the history of electricity. The generation of electrical effects by friction was the basis for a number of electrical machines. Otto von Guericke (1602–1686), famed for his famous experiment in which teams of horses could not separate the halves of an evacuated sphere, employed a ball of sulfur rotated by a crank and rubbed by the hand, prior to the Van de Graaff generator (The Great Courses Daily, 2021). The sulfur ball was replaced by a glass sphere by Isaac Newton. Improved devices that used glass disks and Leyden jars to hold larger quantities of charge were critical instruments for understanding electricity's many characteristics.(The Great Courses Daily, 2021)

One of the great pioneers of electrical research, Benjamin Franklin, utilized such a machine and made a modification that was the key to the Van de Graaff generator in future years. In close proximity to a charged body, he demonstrated that pointed needles carry large amounts of electricity. He utilized this in his famous demonstration performed in the year 1751, that lightning was an electrical phenomena and that electricity extracted from his kite string had all the attributes of electricity generated in the lab by the friction machine (The Great Courses Daily, 2021)

Van de Graaff generators had become extremely popular for their intriguing properties, particularly what is shown in Figure 2. Generations of students have watched their hair stand on end when putting one hand on the generator. Van de Graaff wanted to provide a physicist standpoint on a way of accelerating particles for atomic research. With this, his device has become familiar to a much wider audience as a means of demonstrating many of the principles of electrostatics (Zavisa, 2020).

Technical

Typically, Van de Graaff generators produce very little current (measured in microamperes). As a result, while an inadvertent shock from a Van de Graaff generator may be shocking and unpleasant, most people will not be seriously harmed, even if the voltage is considerably high. The discharge may activate neurons and cause muscles to tense for a limited period of time, but it will not cause heat burns or cell damage. (flinnsci.com, n.d.)

Because the total resistance of the shocked individual and the voltage discharged by the Van de Graaff generator are used to estimate the current strength, it is difficult to determine (potentially up to 500,000 volts) A Van de Graaff generator static discharge lasts only a few seconds. However, even a little quantity of electric current passing through the body can cause issues and accidents. (flinnsci.com, n.d.)

PROCEDURE

Materials and Design

The Fun Fly Stick Company designed a generator, similar to the Van de Graff, and made it a safe, handheld device. Some experiments it can perform include bendig a thin stream of water, move a conductive cylinder, power a neon lamp, perform electrostatic adhesion, and levitation of various shapes with its properties.This particular device is the basis of the experimentation involved. It is a simple, portable version of the well-known Van de Graaff electrostatic generator, as seen in Figure 3. Figure 4, reveals the inside components of the Fun Fly Stick with the rubber belt, metal, and teflon pulleys and metal combs exposed (*talkphysics*, n.d.).The Fun Fly Stick kit comes with one Fun Fly Stick levitation wand, ten pre-cut tinsel flying shapes and manual. However, to operate the device, two AA batteries are required, and are not included.

Methods

The provided instructions from the science kit were used to perform the experiments. Figure 3 demonstrates the kit that was used. The results demonstrate sub- experiments that were constructed from the Fun-Fly-Stick kit.

RESULTS

The Fun Fly Stick is designed to look like a "small Van de Graaff Generator" and functions similarly. A Van de Graaff generator extracts electrons from the Earth, transports them down a belt, and stores them on the huge sphere. Similar to the portable gadget, the Fun Fly Stick, these electrons reject each other and aim to move as far away from each other as possible, spreading out across the surface of the sphere. The results demonstrate sub- experiments that were constructed from the Fun-Fly -Stick generator.

1 The Van De Graff Generator

Van de Graaff Generator

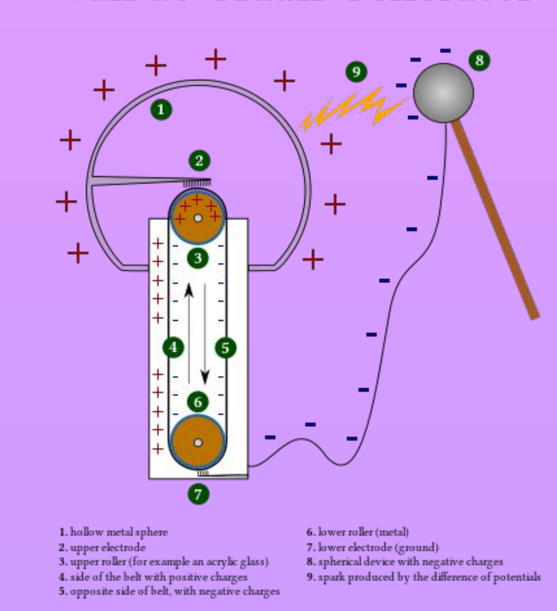

Figure 1.With the Van de Graaff generator on, a few inches from the to the sphere, the breakdown of the air between the generator and the wand, produce sparks, as shown. (Katz, n.d.)

2 Van de Graaff Generator Effects

Figure 2. When the Van de Graaff generator starts charging, it transfers the charge to the person who is touching it. Since the person's hair follicles are getting charged to the same potential, they try to repel each other. This is why the hair actually stands up. (Fisher Scientific, n.d.)

3 The Fun Fly Stick- The Handheld Van De Graff Generator

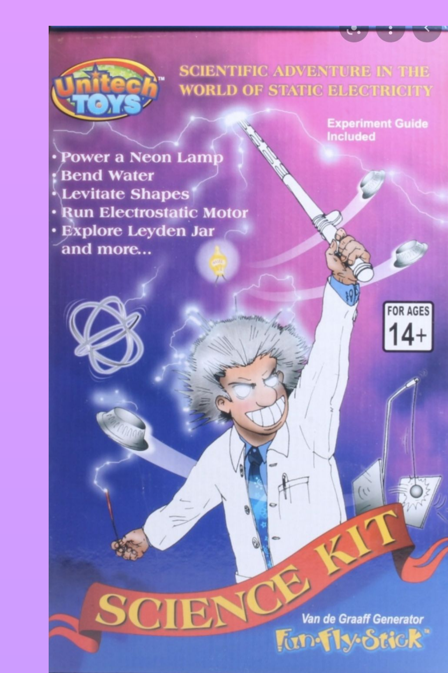

Figure 3. The generator used for the basis of this research is shown above. The Fun Fly Stick is the portable version of the well-known Van de Graaff Electrostatic Generator. (*talkphysics*, n.d.)

4 The Fun Fly Stick Components

Figure 4. Inside parts of the Fun Fly Stick with the rubber belt, metal and teflon pulleys and metal combs exposed (*talkphysics*, n.d.).

5 The Water-Bending Experiment

Figure 5. The bending of a narrow stream of water was achieved by covering the control tube of the Fun Fly Stick with a plastic zip lock bag. The positive charge of the Stick attracts the negative poles of these polar molecules.

6 The Flying Saucer and Floating Shape Experiment

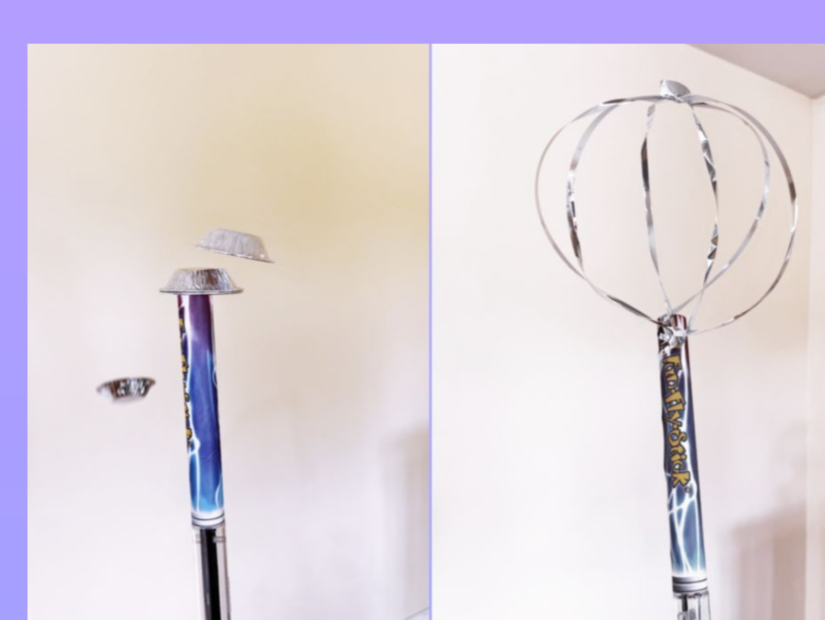

Figure 6. Due to electrostatic forces of repulsion between the pie tins, the tins will fall off the stack one by one. With the floating shapes, similarly, the negative ion generator is included within the electrical circuitry of the device's handle. To produce a negative static charge, simply push the button for a few seconds. Drop the tinsel form onto the stick to swiftly transmit the negative charge, and it will float.

7 The Electrostatic Drummer Experiment

Figure 7. The hanging bead should bounce between the two metal plates when the Fun-Fly-Stick is engaged, creating a drumming sound.The neutral conductive bead is attracted to the positive plate due to induction. Once it touches the plate it acquires the same charge and is repelled away.

CONCLUSIONS

At the point where the rubber belt and teflon pulley pathways separate, electrical charges are separated. The belt has an excess positive charge, whereas the teflon pulley has a net negative charge. The bottom comb "sweeps" the extra electrons from the pulley and sends them to ground through the operator (*talkphysics*, n.d.). Free electrons from the accumulator are then drawn into the upper comb and onto the electron-deficient belt when the positive belt passes over the top metal pulley. The electrons are then transferred to the lower pulley, where the cycle is repeated. Through the metal rim of the button, the bottom comb is linked to the operator's finger. (*talkphysics*, n.d.) The Fun Fly Stick is designed to look like a "small Van de Graaff Generator" and functions similarly. Similar to the portable gadget, the Fun Fly Stick, these electrons reject each other and aim to move as far away from each other as possible, spreading out across the surface of the sphere.

The one noticeable component missing from the Fun Fly Stick is the Van de Graaff generator's usual spherical metal dome. Boris Kriman, the inventor, desired a charge accumulator without the spark' discharge, so he devised a cardboard tube. When exposed to high voltage electricity, cardboard has a high electrical resistance yet becomes a conductor (*talkphysics*, n.d.). Furthermore, it discharges considerably more slowly than metal, eliminating the shock discharge experience. The end result is a toy that is safe for children to play with while causing no discomfort to the operator. (*talkphysics*, n.d.)

The first experiment conducted, the bending of a narrow stream of water was achieved by covering the control tube of the Fun Fly Stick with a plastic zip lock bag, as shown in Figure 5. The control tube must not be soaked. Allow a thin trickle of water to run from the faucet: the narrower the stream, the better. With the activated protective control tube, approach the stream. The stream's bending should depict the water's attraction to the charges on the Stick. Because water molecules are polar and organize themselves in an electric field, they behave as tiny 'magnets' when they come together. The positive charge of the Stick attracts the negative poles of these polar molecules. (*talkphysics*, n.d.)

Figure 7 shows an example of stack pie tins (small tart tins). With the transfer a charge to the stack using the charged wand, the tins start to fall off the top, one by one. Due to electrostatic forces of repulsion between the pie tins, the tins will fall off the stack this way. . The tins will resist one another off the stack due to their respective weight .Figure 7 also demonstrates how floating shapes occur. These shapes, made out of tinsel, were very dainty. The negative ion generator is included within the electrical circuitry of the device's handle. To produce a negative static charge, simply push the button for a few seconds. Drop the tinsel form onto the stick to swiftly transmit the negative charge, and it will float (Stevespanglerscience, 2008)

In the completion of Figure 8, the pin-hanger was inserted into the plastic pin holder for the electrostatic drumming experiment. After attaching the lengthy fishing line with a small metal ball like structure attached to then end of the pin, leaving the bead dangling down, two metal plates were inserted into the openings on the plastic support. With the bead in-between the metal plates, plastic support with the plates under the pin-hange was then added. The, touch one metal plate with a finger and maintain it in touch with it for the duration of the experiment. Finally with the Fun-Fly-Stick, approach the opposite plate. The hanging bead should bounce between the two metal plates when the Fun-Fly-Stick is engaged, creating a drumming sound. (*talkphysics*, n.d.) This demonstration is a great incorporation of induction and charge attraction and repulsion. The neutral conductive bead is attracted to the positive plate due to induction. Once it touched the plate it acquired the same charge and was repelled away. (*talkphysics*, n.d.)

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