Van de Graaf Generator and Franklin's Bells

The Van de Graaf generator is a relatively simple and inexpensive source of large electric potential difference, i.e., voltage, based on simple electrostatics. Though large-scale models are used in particle accelerators and industrial applications (sterilization, radiography, medicine, and radiation processing of plastic), small-scale models may be used in classroom laboratory experiments ("particle accelerator" 11). At sufficiently low current from a source such as an average retail battery (AA, AAA, C-cell, D-cell, etc.), the voltage generated is safe for humans. The small-scale model discussed below should generate a spark a few centimeters long of about several thousand volts. However, the nature of the design, available measuring devices, and time constraints provide no method of quantitative measurement of current or voltage, which only allows for qualitative experimentation. As an alternative, this generator is used to operate a simple electrical device called "Franklin's Bells," which Benjamin Franklin popularized for detecting lightning during thunderstorms.

Van de Graaf Generator

The simple model discussed below includes an insulating casing made of PVC pipe attached to a painted wood board, which is also an insulator, to prevent interference with the operation of the device. An empty soda can is the terminal for dissipating voltage. A small DC motor, purchased from RadioShack, with a plastic extension to the axle; a small glass tube from a fuse mounted to a steel nail; and a rubber band form a system of two pulleys and a belt. Two wire brushes, one from the ground (the operator) to the belt and another from the belt to the terminal, consist of wire segments each with one frayed end. The terminal is mounted to the casing by a plastic collar (the top of a plastic water bottle).

Triboelectric Series

The tribolelectric effect (from Latin: terō, terere, trīvī, trītum "to rub, to wear out/away") refers to the tendency of different materials to lose or gain electrons when rubbed against each other (Morwood 262; Zavisa). Examples of this include content from PHYS 2074H (Stewart "Activities 1 and 2" and "Chapters 2 and 3").

Corona Discharge

Like charges repel by Coulomb's Law, and all electrons are negatively charged, so electrons *ceteris paribus* will tend to maximize their separation. At a sharp point of a conductor surrounded by a suitable gas, e.g. a metal point surrounded by air, the electrons in the rest of conductor repel the electrons in the point and the gas exerts no repulsion because any negative charges in the gas have been readily dispersed. A sufficiently large negative charge in the conductor will discharge electrons in the point into the gas. The gas molecules are energized by the electrons, which may release a crown-shaped arc of dim light. These negatively charged air molecules (the air is ionized) repel each other, which one may feel by a small wind. Hence the name “corona discharge.” The reverse occurs with positive charges.

Disperse of Charge on a Rounded Conductor

On the basis of repulsion of negatively charged electrons, electrons in a conductor will disperse to maximize their separation. In a spherical or cylindrical conductor, such as a metal soda can, these electrons should stay in the conductor because there are no sharp corners where discharge into the air may occur.

Operation

Based on the relative positions of glass and rubber in the triboelectric series, the tube tends to lose electrons to the belt as the they rub together during motor operation. Like charges repel, so concentrations of like charges will *ceteris paribus* maximize their separation. However, the tube has small volume and surface area relative to the belt, so positive electric charge is relatively concentrated on the tube and negative electric charge is relatively dispersed on the belt; the former exerts a stronger electrical force than the latter on external charges at the same distance.

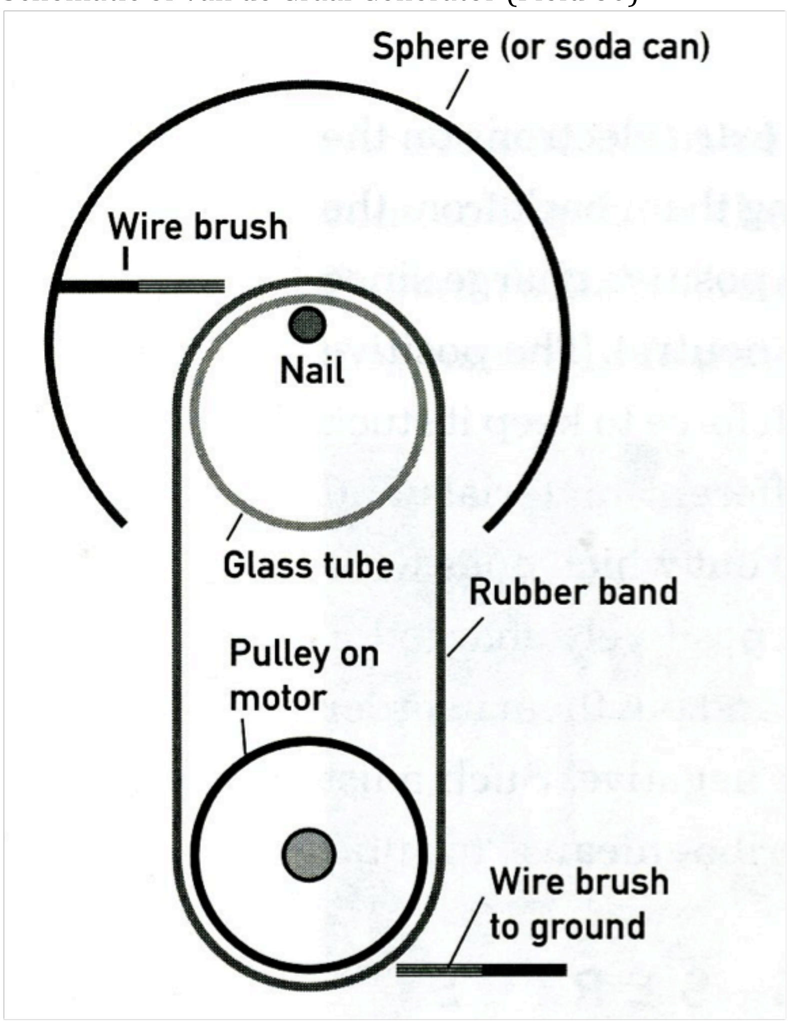
The tube should be sufficiently positively charged to cause the top wire brush to discharge electrons in the air. However, the belt has relatively dispersed charges and covers the tube, so the it readily accepts these electrons. At the lower pulley, the negatively charged belt repels the electrons in the grounded brush; the electrons are transferred to the ground and the points of the brush become positively charged. This discharges positively charged air, which is attracted to the band. Subsequent charge transfers such that the band and the air are restored to neutrality and the band returns to the upper pulley.

At the upper pulley, the brush connected to the terminal continues to draw electrons from the terminal. Thus, the terminal becomes increasingly positively charged and this charge is distributed throughout the terminal. When the terminal is sufficiently charged and an external object sufficiently close, electrons will move from the external object to the terminal. This releases energy as light.

Franklin's Bells

An electrically isolated pull-tab is mounted between two soda cans in such a way that it could swing back-and-forth from one can to the other. Can (1) is attached by wire to the terminal of the Van de Graaf generator and Can (2) is attached by wire to the grounded brush of the generator. The generator positively charges (1), which separates charge on the tab. The negatively charged side tab is attracted to (1), so the tab towards (1) [this may need a push]. On contact, (1) and the tab both develop positive charges, which repels the can toward (2). This induces charge separation in (2) such the tab is also attracted toward (2). On contact, the excess positive charge on the tab is transferred to the ground. The neutral tab then swings back by gravity and the attraction of (1).

Schematic of Van de Graaf Generator (Field 60)



Works Cited

Field, Simon Q. *Gonzo Gizmos*. Chicago, IL: Chicago Review. 2002. Print.

Morwood, James. "Tero, Trivi, Tritum." *The Oxford Latin Minidictionary*. 2nd ed. 1995. Print.

"particle accelerator." *Encyclopædia Britannica*. *Encyclopædia Britannica Online*. Encyclopædia Britannica, 2010. Web. 18 Apr. 2010 <http://0-search.eb.com.library.uark.edu/eb/article-60510>.

Stewart, John, and Gay Stewart. "Activities 1 and 2." *Spring 2010 University Physics II - Activity Guide*. Fayetteville, AR: University of Arkansas, 2010. Print.

Stewart, John, and Gay Stewart. "Chapters 2 and 3." *Spring 2010 University Physics II - Course Guide*. Fayetteville, AR: University of Arkansas, 2010. Print.

Zavisa, John. "HowStuffWorks "Static Electricity"" *Howstuffworks "Science"* Web. 18 Apr. 2010. <http://science.howstuffworks.com/vdg1.htm>.