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Physics II Honors Project

Van De Graaff Generator

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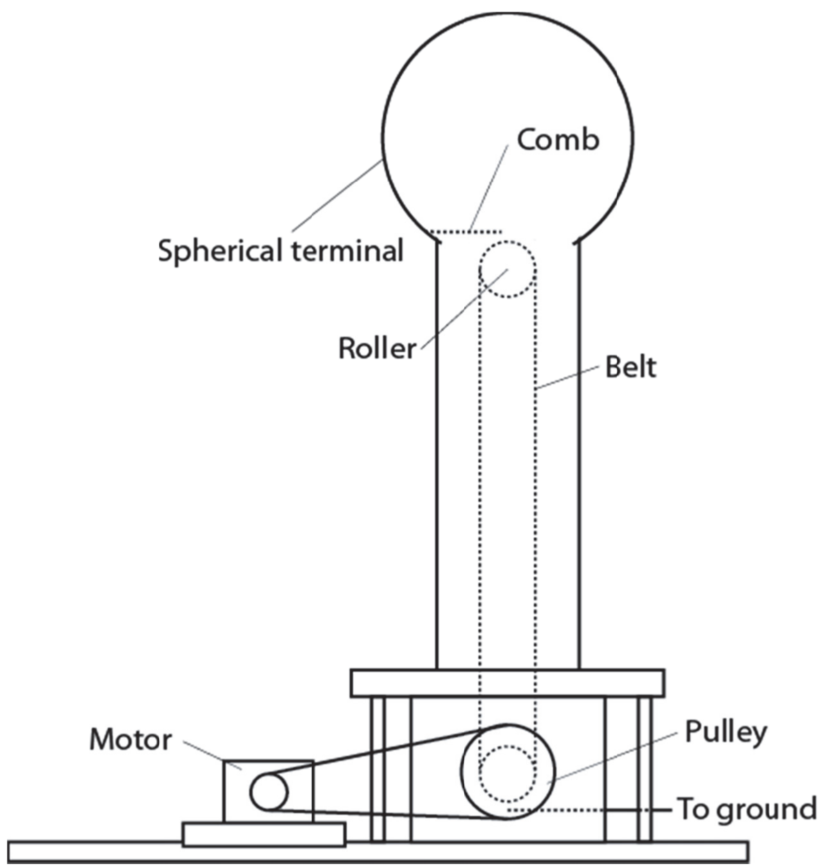
Robert Jemison Van de Graaff, in 1931, filed a patent for an electrostatic generator unlike anything the world had ever seen. His generator, unlike those before it, was capable of producing 750,000 easily usable volts (Encyclopaedia Britannica 2011, 188). The goal of this project was to construct a generator similar in design and principle to Dr. Van de Graaff's machine. A diagram of the completed generator can be seen below. Van de Graaff generators are relatively simple devices. They most basically consist of two rollers made of different materials, a dielectric belt, a conducting spherical terminal, two metal combs and a driving motor. The two driving principles of every Van de Graaff generator are triboelectricity, and corona discharge.



The triboelectric effect is what causes one's hair to stand on end after being rubbed by a balloon. When two materials come into contact with each other, they form chemical bonds. When they are removed from each other, those bonds are broken, but a net exchange of electrons takes place between the materials (Moore 1995, 26). How many electrons and which material experiences the net increase depends on the relative positions of the two materials on the triboelectric scale. On the negative side of the scale lie materials such as Teflon and vinyl, while on the positive side of the scale lie materials like human skin, glass and animal fur. A relatively negative material, and relatively positive material, when brought into contact with each other, will become negatively and positively charged, respectively (Whitaker 2007, 154). In a Van de Graaff generator, as the belt comes in contact with the bottom roller, made of plastic, the roller becomes positively charged, and the belt becomes insignificantly negatively charged. After some length of operation the bottom roller develops a relatively strong positive charge, which causes a corona discharge at the bottom comb.

Corona discharge, famously responsible for terrifying many a sailor as “St. Elmo’s Fire”, is the other driving principle of every Van de Graaff generator. When a relatively strong negative charge exists on a conductor, any oxygen molecules that come near it are ripped apart into electrons and positively charged oxygen molecules. The electrons are repelled from the negatively charged surface and collide with other oxygen molecules, knocking their electrons free. This creates plasma at the surface of the conductor (Moore 1995, 147). The bottom comb in the Van de Graaff generator is made of metal, which, as a conductor, allows its electrons to move about freely. The strongly positive roller attracts the electrons in the metal comb, and the electrons move to the tips of the comb. Eventually the concentration of electrons at the tips of the comb is so strong that it causes a corona discharge. Meanwhile, the free electrons in the plasma created by the corona discharge are attracted by the roller, but stick to the belt on their way there. The positively ionized oxygen is attracted to the comb, gains electrons, and the whole process repeats itself (Beaty). A Van de Graaff generator needs oxygen to operate; if in a vacuum, the Van de Graaff generator will not induce a charge on the conductor.

The belt carries the electrons from the bottom of the apparatus to the top roller, which is covered in foil, and therefore neutral. Something similar to what happened at the bottom roller happens here. The electrons on the belt repel the electrons in the upper comb, exposing positive atomic cores. The air becomes ionized between the belt and the comb; the electrons rush onto the comb, and the positive oxygen molecules are attracted to the belt. The electrons on the comb are placed on the conducting terminal, while the oxygen molecules cancel out the belt's negative charge (Beaty).

Van de Graaff generators can be adversely affected by many different things. Anything that prevents contact between the surface of the belt and the surface of the rollers will cause the generator to cease to produce charge. Oil from human skin, dust, and moisture all will interfere with contact generation. Before operation it is advisable to wipe the belt and rollers with rubbing alcohol to remove dust and grease. Corona discharge, although integral to the operation of a Van de Graaff generator, can also be its bane. If the spherical conductor has sharp edges or even scratches on its surface, charge will leak out and cause the Van de Graaff generator to be much less effective (Ford 2001, 92). Humidity will cause the voltage produced by a Van de Graaff generator to fall significantly; the water in the air will cause insulating surfaces to behave like conductors.

Van de Graaff generators are electrostatic generators that rely on the triboelectric effect, corona discharge, to operate. When working properly and under the right conditions, they can produce static charges of tens of thousands of volts.

Works Cited:

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