Construction of a Van de Graaff Generator

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Introduction

The goal of this project was to construct a functioning Van de Graaff generator from easily accessible parts and to display a knowledge of the underlying physics behind the generator upon completion. Components of a Van de Graaff generator include a hollow conducting sphere, a pulley system, two rollers, two metal brushes, and a ground. In an effort to save money, our project was simplified so that most of our supplies could be purchased from Lowe's and Wal-Mart.

History

After attending several of Mme. Curie's physics lectures in Sorbonne, Robert J. Van de Graaff became fascinated in high-velocity particles, having witnessed demonstrations of alpha particles emitted from radioactive sources. Van de Graaff discovered that he could transfer large amounts of charge from a ground potential to an isolated sphere to generate high voltages; his purpose for creating his namesake generator was to make "…a copious supply of atoms and electrons…" for his research (Bygrave 3). Using a small can, a silk ribbon, and a small motor, Van de Graaff was able to produce an 80 kV generator in 1929. From his simple initial design, improvements have been made to increase the obtainable voltage from the generator through the use of varying materials.

Underlying Physics

This project was constructed using a simplified version of the Van de Graaff generator where the triboelectric effect is utilized (Van de Graaff generator). In the triboelectric effect, electric charge is created through the contact and subsequent separation of two materials on opposite ends of the triboelectric series. This charge is caused by the breaking of chemical bonds that form between the differing materials. The triboelectric series ranges from materials

that tend to lose electrons through contact (giving them a positive charge) to materials that tend to keep extra electrons (giving them a negative charge) (Triboelectric effect). The triboelectric effect comes into play in two places in the generator: the contact between the pulley belt and the top roller and that between the belt and the bottom roller. To maximize the impact of the triboelectric effect, the rollers should be made of materials on opposite ends of the series while the belt should lie somewhere in between. This creates an area for the creation of positive charge and one for negative charge. As the belt travels the length of the generator, however, the triboelectric effect will cancel out as a negatively-charged area of belt will arrive at point of contact with a material that tends to keep extra electrons. To prevent the negation of this charge, the charge is removed from the belt as soon as it is created by the metal brushes; the charge is extracted from the dielectric belt through a corona discharge. A corona discharge occurs when a strong electric field is created near an object under high electric stress, in this case the pointed tips of the brush bristles (Electrical breakdown). The discharge causes charge to transfer from the top roller of the belt to the conducting sphere where the like charges spread out across the outer surface.

Construction of the Van de Graaff Generator

Our Van de Graaff generator was constructed following an online guide with improvements made as certain parts of the generator failed to work (or cooperate); for reasons of cost and availability, some significant changes were made to the online design. The hollow conducting sphere was constructed from two large metal mixing bowls. A hole was cut into the bottom of one, and the two bowls were taped together with electrical tape; rather than to provide any insulating effect, the tape was used to prevent corona discharge from the edges of the bowls. The pulley system was altered from the suggested motor/pantyhose combination. A 12V hand-

drill was used instead to move the dielectric belt; after attempting and failing to make a viable belt out of pantyhose, it was decided that caution tape would be a better choice. Caution tape provided an easier-to-manage option for a belt as it could be cut to size more easily without the need for hardening adhesives. Two differing materials were chosen for the ½ -inch PVC rollers to make full use of the triboelectric effect; the top roller was covered in aluminum foil, a loser of electrons, while the bottom roller was covered in electrical tape (vinyl), a keeper of electrons. To pull away charge at either end of the belt, metal brushes were created by stripping the ends of insulated copper wiring and fraying the strands. The top brush was connected directly to the inside of the conducting sphere, transferring positive charge from the positively charged aluminum roller and belt section to the sphere, while the bottom brush was connected to a ground wire, transferring negative charge from the negatively charged vinyl roller and belt area to a grounding wand constructed from PVC and a doorknob. The pulley system was encased in a 3-inch PVC pipe to insulate the system from outside electrical influences. A hole was cut into the side of the PVC near the top to allow easy access to the top roller. The base was constructed from a bucket into which a hole was cut for the PVC to sit in; the PVC was attached to the bucket using metal brackets that were insulated. Inside of the bucket, the drill was attached directly to the bottom roller, spinning it to cause the spinning of the belt.

Results

On several attempts, the caution tape began bunching up at one end of the roller, preventing any sort of charge build up. When using a narrower width of caution tape, it was seen that the belt ran more smoothly with only small hiccups. After running the drill for approximately 15 seconds, the presence of charge on the sphere was detected by the spark that

occurred after touching it to the grounding wand. Several more attempts were performed resulting in similar sparks with approximately 1-centimeter lengths.

Conclusion

This project resulted in the successful construction of a Van de Graaff generator. The primary measure for the success of this project was the creation of a spark, indicating the presence of charge on the conducting sphere. The traditional "hair standing on end" experience attributed to Van de Graaff generators was not feasible for this project as the available materials and budget restricted the construction of a high-powered generator. All-in-all, the project cost about $65 with the bulk of the cost going to the mixing bowls at $13 apiece, a small price to pay for the furthering of physics education. Currently, the generator is ready to be submitted, but some alterations will be trialed prior to the in-class demonstration to see if there is area for improvement.

Works Cited

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