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HONORS PAPER

Non-working Van de Graaff generator

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Purpose

The goal of this project was to build a working Van De Graaff generator with supplies from common shopping locations (i.e. Wal-Mart, Lowe's, and Home Depot) using a metal bowl, rubber belt, Polyvinyl Chloride Pipe (PVC Pipe), and a wire brush. In the end, the project used three types of brushes and two different motors, yet it never worked properly.

History

The Van de Graaff generator was built and designed by Dr. Robert Jemison Van de Graaff of the Massachusetts Institute of Technology. He began building and designing his first generator in 1927 and completed it in 1929. The original uses of the Van de Graaff generator were to research the splitting of atoms and the effects of accelerating high energy ion beams. At first, a clear tube was ran between a Van de Graaff generator and an analysis tower that measured the effects of varying voltages that were tested on objects placed inside of the tube.

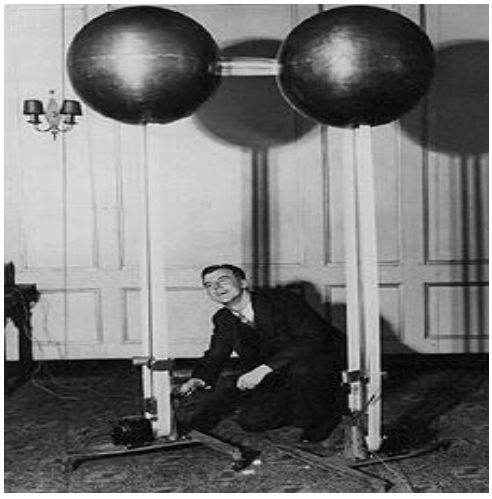

Figure 1

Dr. Van de Graaff with one if his first generators

(www.mos.org)

The first Van de Graaff generator used a silk belt to transport the charge from the bottom roller, where the charge was introduced to the belt via an electric current motor, to a metallic shell that was mounted on the top of a Pyrex tube. After many successful tests and lots of tinkering Van de Graaff achieved a remarkable 1,000,000 volts across the two towers in 1931. Once Van de Graaff and MIT were granted a joint patent, he then built a forty-foot tall generator at MIT's Round Hill facility.

Today, the highest achieved voltage from a Van de Graaff generator is 25.5 million volts. Small generators are commonly used by museums and universities to demonstrate the effects of lightning and electricity to class groups and the general public. The Van de Graaff generator has had many updates including the replacement of the silk belt at first to a rubber belt and now to a belt made of metal, interlocking rods. The metal belts allow for much higher rotational velocities because they don't stretch or slip nearly as much.

Traditionally Van de Graaff generators were surrounded by air but recently physicists have used other gases such as Sulfur Hexaflouride (SF_8) to run the generators in. The SF_8 is used because the static charge on the surface of the conducting sphere is less likely to randomly discharge than it is in the air (Loucas).

The physics of a Van de Graaff generator…

The Van de Graaff generator uses the triboelectric charging, charging an object by making contact between two materials then moving them apart as in rubbing of lifting, to build a static charge on the outer surface of a

conducting sphere. The first known example of triboelectric charging was between amber and wool by Thales of Miletus (Ryne). Van de Graaff used glass and silk for his original designs.

Tribolectric charging exists in two places in a Van de Graaff generator. The first place is between the bottom roller and the belt at which point chemical bonds form and are broken between the material of the belt and the material of the roller. One of the induced charges gather on the surface of the belt and are moved upward whilst the opposite charge is built up on the roller then transferred to the ground through a grounding rod. The second place is between the top roller and the belt in which the same events occur without the charge being grounded in the roller. This separation of charge does not occur in the top because the top roller is not grounded as the bottom one is.

The second place the Tribolectric charging occurs is between the brush and the belt. As the brush makes contact with the belt the charge is transferred between the belt to the brush and then to the outer shell. According to Ohm's Law, the charge on a conductor is spread evenly across its

outer surface. This means no matter where the outer shell gets touched, someone will get shocked.

Construction of a nonworking Van de Graaff generator

The following figure demonstrates the Van de Graaff generator was set up including all induced charge.

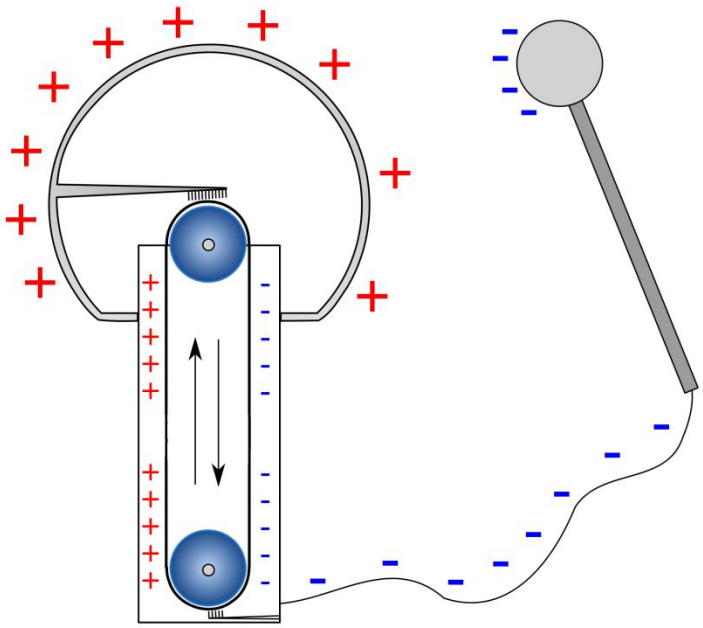

Figure 2

Basic design for a Van de Graaff generator

(www.wikipedia.com)

The project began by building a base housing for the main PVC housing. This was done by cutting a hole out of a two

by four with a two-and-a-half inch hole drill. The PVC housing was then inserted into the hole and secured in place using shelving mounts. Another two cuts of wood were used for stability.

As far as the rollers went, Polyethylene was wrapped in aluminum foil on the top and polyethylene was wrapped in vinyl on the bottom. These three materials were chosen due to their physical properties as well as their electrical tendencies. The Polyethylene was used because the hardly creates any heat with the metal axel. The aluminum foil and vinyl were chosen because aluminum foil has a tendency to not hold a charge and to readily give it away whilst the vinyl has the opposite effect. These two materials are responsible for the Tribolectric charging to take place because they allow the electrons to move easily from one material to the other.

In this project, three types of brushes were used. The first brush was a hard, wire brush with copper wire intertwined between the bristles so as to transfer the charge. This brush didn’t work because the bristles were too hard and ended up shredding the belt into pieces.

The second brush was the same brush, but modified. We cut the bristles and soldered them to a wire and let them rest gently on the belt so they could move freely if they needed to. This didn't work because the bristles wouldn't stay attached to the wire as the moving belt would force them to break from the soldering.

The final brush type was a very soft wire brush used to clean golf balls. This time, a wire was soldered to both sides of the bristles and then rejoined on the side of the brush. The handle was cut off so the main part of the brush could be mounted to the PVC pipe with a three inch screw.

The rubber belt that was used was a small fan belt for a vacuum cleaner. It is believed that this was the main reason the generator didn't work. The belt was too thick to properly transfer the charge. The reason this belt was chosen was no better fit could be found using the parameters set in the purpose. There were no exercise bands or caution tape at Wal-Mart at the time of supply-gathering.

The first motor used was a 12V cordless drill made by Toshiba rated at 575 rotations per minute. This is thought

to have not worked because it wasn't able to rotate the belt at a high enough velocity to transfer the charge fast enough for the charge to build on the conducting shell. The second motor was a corded power drill by Rigid rated at 1200 rotations per minute.

The grounding rod was made of a copper tube with a smaller metal sphere soldered to the end and rubber shrink-wrap around the other end to act as a safe handle. The wire for the grounding rod was soldered to the bottom brush then covered in shrink wrap for safety purposes.

Finally, all the sub-sequential pieces were put together and tested multiple times to discover that there would be no shock from this project. Had the project not been limited by the use of everyday items, the project should have looked like Figure 3 located after the conclusion.

Conclusion

The goal of this project was to build a working Van de Graaff generator using commonly found items. The Van de Graaff generator in this project was never able to produce a spark. The flaws in this design were found to be due to the availability and quality of the parts needed.

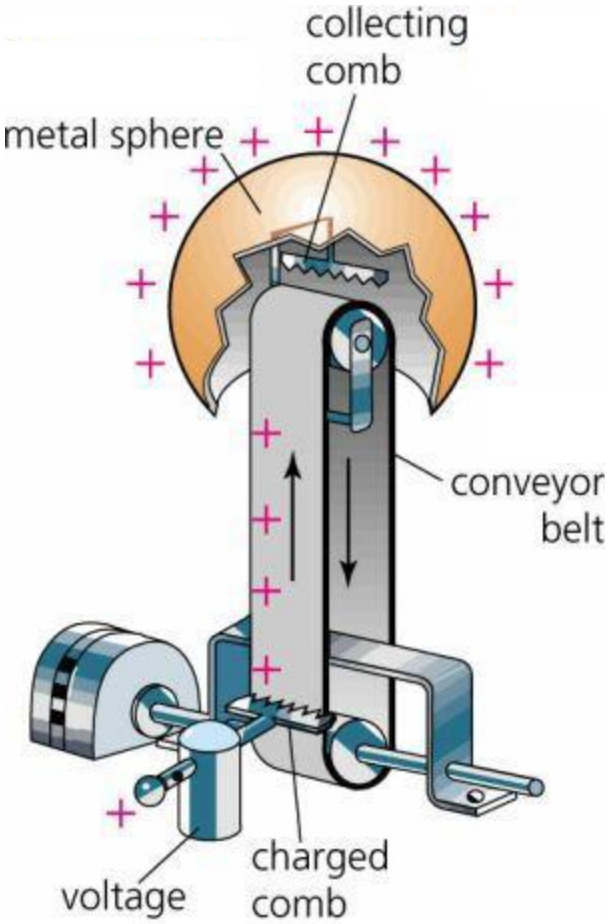

Figure 3

Design of expensive Van de Graaff generator

(Courtesy of www.chem.ch)

Works Cited

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2) Christophorou, Loucas G., Isidor Sauers, ed (1991). *Gaseous Dielectrics VI*. Plenum Press

3) "Robert Jemison Van de Graaff." 2002. 22 Sun 2009 <http://chem.ch.huji.ac.il/history/graaff.html>

4) http://www.mos.org/sln/toe/history.html © 1995 Museum of Science, Boston