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University Physics II- Honors Project

Van de Graaff Generator

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Historically, the Van de Graaff generator was invented by Robert J. Van de Graaff, who demonstrated a potential difference of more than 80 kV between the terminals of two belt-charged generators (Bygrave, Reado, and Lambert, 22). The generator that was built for the project has a much lower voltage and is safe for the lab presentation setting; it is a mini-scale version of what was originally built by Robert Van de Graaff. As all Van de Graaffs are, it is constructed of a motor, a belt, an upper and lower roller, an upper and lower brush, and a sphere. The generator emits lightning-like sparks, which relieve the concentration of charge (Zavisa 2000). Three principles are integral in the functioning of the Van de Graaff: The Lorentz Force, by which the motor on the generator produces mechanical energy from electrical energy; the triboelectric effect, by which charge separation between the belt and each of the rollers occurs, and corona discharge, by which charge is transported and built up.

The motor used for the generator was a motor taken from an old space heater which had shorted out. The motor is very identical to the motors built in lab, where an electric current runs through a coil, which is placed in a magnetic field, to cause a torque, or a rotational force, in this case the Lorentz Force (Stewart 2012). Attached to the center of the rotating coil is a cylindrical shaft, which was extended into the center of the body of the Van de Graaff. This shaft rotates with the rotation of the coil. The overall effect of this is that electrical energy is converted into mechanical energy, which is the purpose of a motor.

The Triboelectric effect occurs when two different materials come in contact and are then separated: Electrons are transferred from one material to the other, so that one of the materials has a positive charge and the other a negative charge (Rehorst 2009). Most every day static electricity can be explained by triboelectricity. In the Van de Graaff generator, the triboelectric effect occurs where the motor-rotated shaft, which has been covered with a plastic tube that rotates with the shaft, comes into contact with the rubber band, and also where the glass-covered wooden shaft at the top of the body comes into contact with the moving rubber band. Because the bottom shaft is covered with plastic tubing, and plastic is a material that is at the negative end of the triboelectric series (RimstarOrg, 2012), the tubing gains a negative charge. Due to the triboelectric effect, electrons are transferred from the rubber band to the plastic tubing, which then has a positive charge. Similarly, the triboelectric effect explains the glass tubing on the top shaft gaining a net positive charge. Glass is a material at the positive end of the Triboelectric series (RimstarOrg, 2012). So when the rubber band and glass tubing come into contact and then separate, the glass tubing has the positive charge while the rubber band is left with a negative charge.

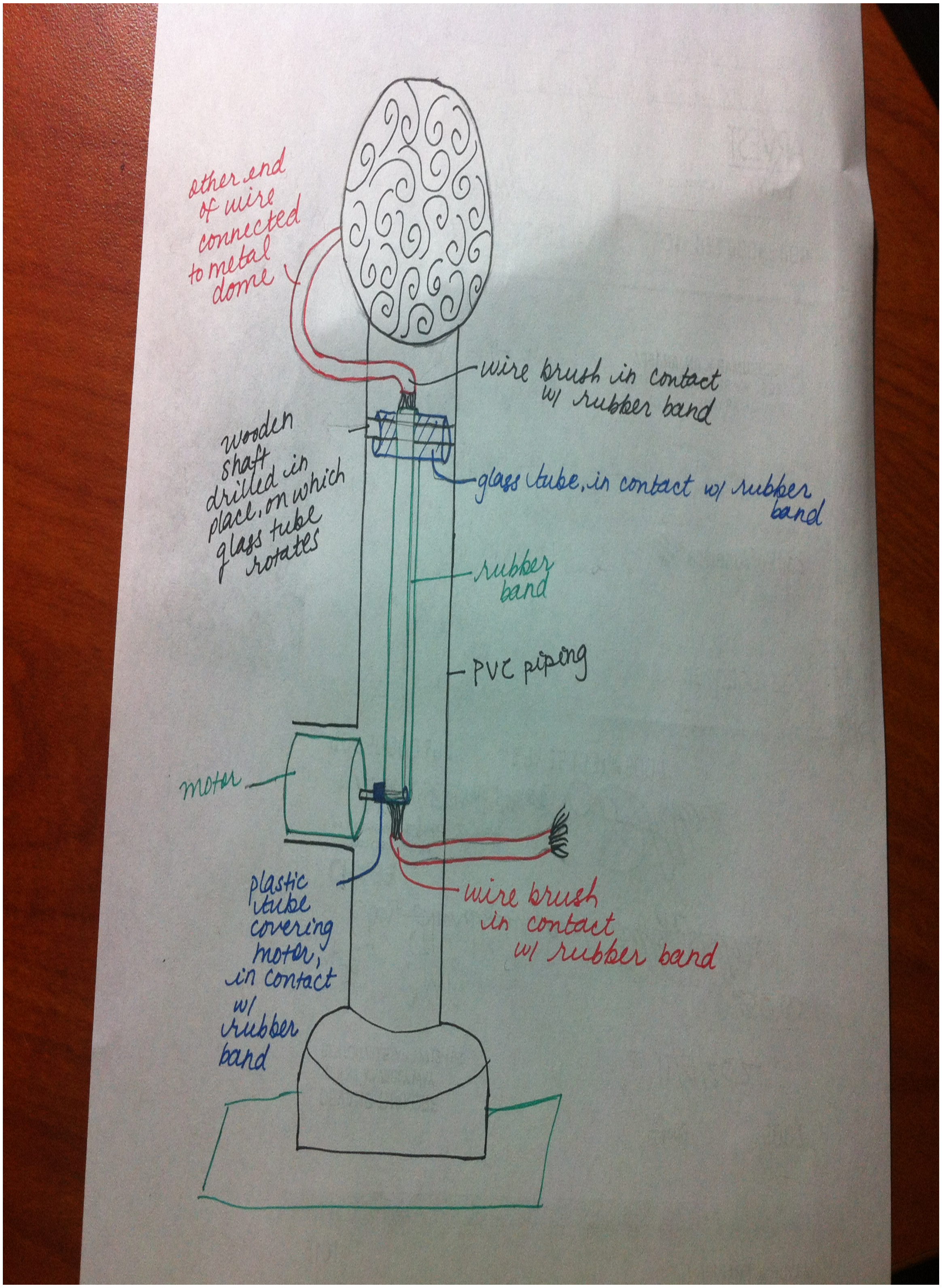
Corona discharge helps to explain more of why the rubber band has a net negative charge when separated from the glass tubing. The brush-like end of a wire was placed near the rubber band. The positively charged glass tubing on the opposite side of the rubber band attracts electrons in the brush to the tip of the brush. An electric field is created between the brush and the band, and air molecules in that field, which include but are not limited to atoms of oxygen and nitrogen, are ionized. Electrons are attracted toward the positively charged glass tubing but are intercepted by the rubber band. The rubber band leaves the glass tubing with these electrons, partially explaining its net negative charge. Positive ions are attracted towards the tip of the brush, and electrons flow along the conducting wire to the tip of the brush as well. These electrons come from the conducting wire but also from the metal dome, which the wire is connected to, leaving the dome with a net positive charge.

This corona discharge also takes place at the bottom roller, where the rubber band moves around the plastic tubing covering the revolving shaft. The plastic tubing, due to the triboelectric effect as stated earlier, has a net negative charge. Electrons at the tip of the brush are repelled away from the tubing, and run through the wire where they can be grounded at the other brush-like end.

As stated above, the metal dome is left with a net positive charge due to the effects of triboelectricity and corona discharge. Grounding this surface can cause a visible electric spark, where the fun in building a Van de Graaff generator lies. The generator that was built can be grounded by bringing one's finger close to (about 1 cm away from) the edge of the dome. The metal sphere used was a home décor item bought from Hobby Lobby and has upraised, swirly metal designs all around it. It was realized after the construction of the Van de Graaff that using a smooth dome would have made a larger, more visible spark. Sharp edges can cause the built-up charge to leak out and not as much can be discharged, causing the lightning-like spark. So, sharp edges and leaking charge lead to a smaller spark. This concept was learned in lab while building electroscopes. However, even with the swirly-designed "sharp" edges, the Van de Graaff that was built discharges through a visible and easily felt spark.

Building the Van de Graff teaches a non-engineering student quite a bit about engineering. The specific concepts that were integral to the functioning of a Van de Graaff generator, like triboelectricity and corona discharge, were learned in depth, and the Lorentz Force was seen in action once again with the crucial motor.

Figure 1



other end of wire connected to metal dome
wire brush in contact w/ rubber band
wooden shaft drilled in place, on which glass tube rotates
glass tube, in contact w/ rubber band
rubber band
PVC piping
motor
plastic tube covering motor, in contact w/ rubber band
wire brush in contact w/ rubber band

Citations

Bygrave, W., P. Treado, and J. Lambert. 1970. *Accelerator Nuclear Physics: Fundamental Experiments with a Van de Graaff Accelerator*. Burlington: High Voltage Engineering Corporation.

John Stewart, and Gay Stewart, "UPII Fall 2012 Fall Course Guide," *Part 2: Magnetism and Optics,* Vol. 2.

Rehorst, Mark. 2009. "Van de Graaff Generator." Last modified March 21. http://mark.rehorst.com/Van_de_Graaff/index.html (accessed March 4, 2012).

RimstarOrg. "How a Van de Graaff Generator Works." Web, https://www.youtube.com/watch?v=EsZQS2GOMQE.

Zavisa, John. 2000. "How Van de Graaff Generators Work." Last modified April 1. http://science.howstuffworks.com/transport/engines-equipment/vdg.htm (accessed March 4, 2012).