Activity 7: Hand Held Van de Graaff Generator

Overview

The Van de Graaff generator is a machine invented in 1929 by American physicist Robert J. Van de Graaff to generate static electric charge. A traditional VDG includes a motor-driven conveyer belt made of rubber going around a Teflon roller at the bottom and a metal roller at the top. A schematic model of a typical VDG generator is shown in **Fig. 1**.

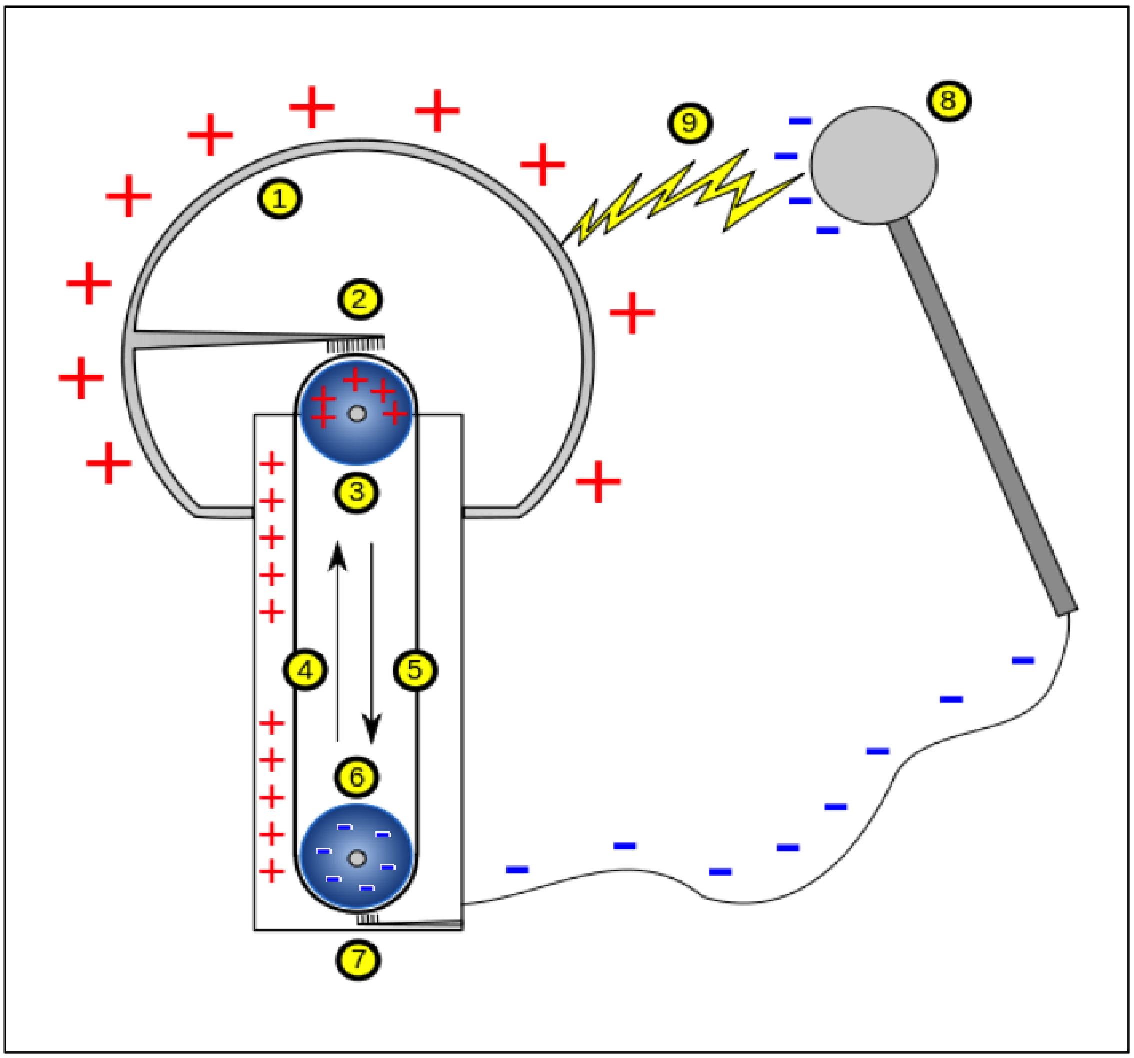

Fig. 1 A traditional Van de Graaff Generator with components 1) Metal dome, 2 &7) Metal brush, 3)Metal roller, 4&5) Rubber belt, 6)Teflon roller, 8)metal sphere, and 9) spark from electric discharge

According to the triboelectric series, rubber loses some of its electrons to Teflon when they come into contact. As the belt revolves, positive charge accumulates on the metal

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

roller and negative charge accumulates on the Teflon roller. When there's so much charge on the roller it can exceed the breakdown potential of air, the insulation, the charge on the roller can leap onto the metal brush nearby. The sharp tips on the metal brush facilitate the leap. The metal dome and the metal sphere act as reservoirs of electric charges. They allow for charges to build up. There is often hundreds of thousands of volts between them. Discharge between the dome and the sphere creates a long and bright spark that can be seen and heard. Our handheld VDG has a small reservoir, which is the front tube made of cardboard. It carries a safe amount of charge to be used in the classroom. **Fig. 2** is a picture of the handheld VDG.

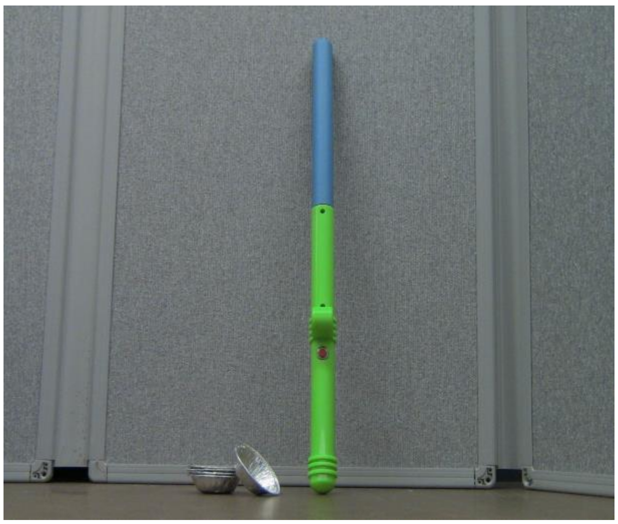

Fig. 2 A photo of the handheld Van de Graaff generator that is safe to use in the classroom.

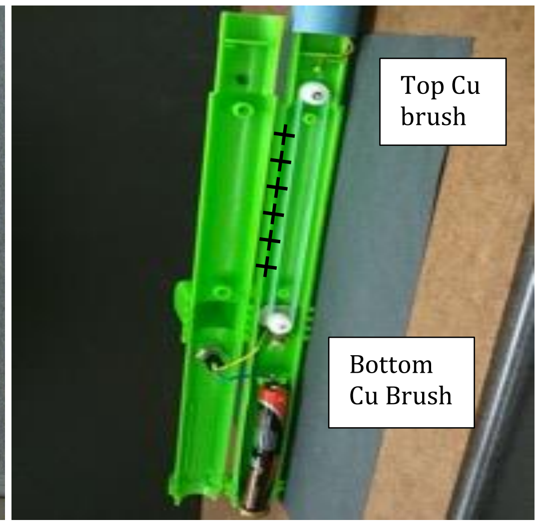

Fig. 3 A cutaway look inside the hand held VDG showing two AA batteries.

Look at the inner workings of your handheld VDG shown in **Fig. 3**. There are two Teflon rollers – one on the bottom and one on the top. A rubber belt runs over the rollers. See **Fig. 4**. Electrical charges are separated at the point where the rubber belt and the bottom Teflon roller separate. The top roller is made of Teflon instead of metal, presumably to reduce cost. It does not participate in charge generation. As we learned from the triboelectric series, the Teflon roller at the bottom holds on to the electrons from the belt and becomes negatively charged, while the belt becomes positively charged as shown in **Fig. 4** and **Fig. 5.**

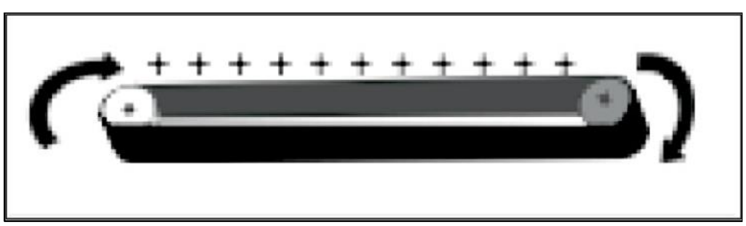

Fig. 4 The rubber belt acquires + charge as it rubs over the Teflon roller

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

There are two copper brushes, one on top and one on the bottom. They come as close as possible to contact with the belt, but never touch the belt directly. The bottom brush is shown in **Fig. 5**.

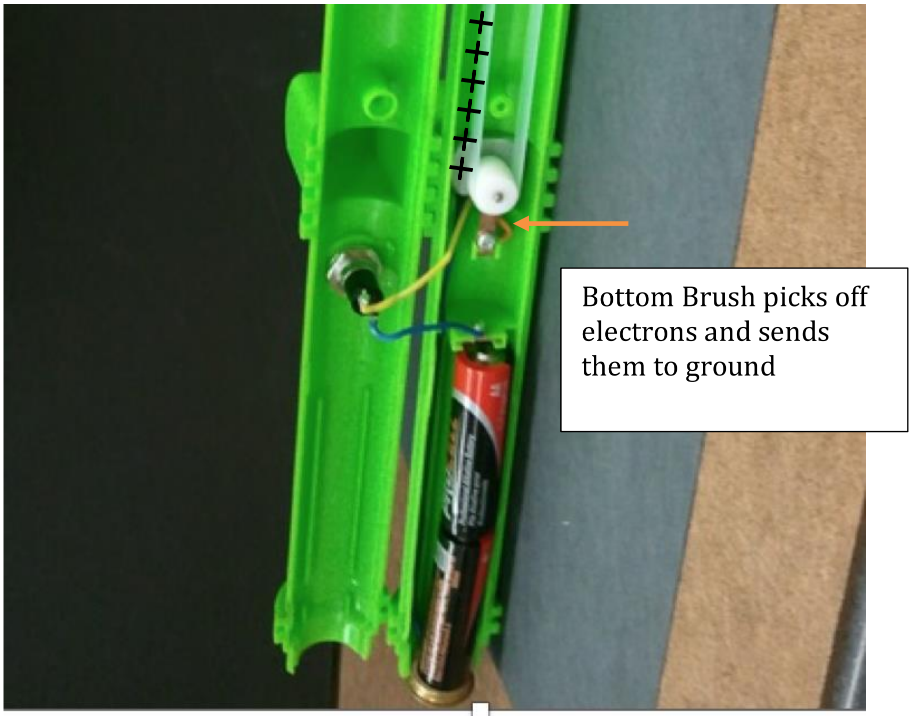

Fig 5. A cutaway view of the VDG showing the two double AA batteries.
The bottom brush collects the negative charge and is wired to the motor casing, which is then wired to the button you push. All the negative charge goes into your body. The top brush collects the positive charge and passes that to the cardboard tube.

The cardboard tube is in direct contact with the upper brush. It serves as a reservoir for positive charge and is analogous to the spherical metal dome on the traditional Van de Graaff generator. A frequently repaired part on the handheld VDG is the top brush. Since the tip close to the rubber belt is constantly exposed to electric discharge, it will become oxidized over time and no longer conduct electricity. **If your handheld VDG stops producing charge, it is likely due to oxidation of the brush. You can take off the top brush and sand its tip to restore its conductivity.** (Bonus question: the bottom brush is usually immune from oxidation; can you guess the reason?)

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

Activity 7-1 Determine the charge polarity on the VDG

Objective: Determine whether positive or negative charge is generated on the cardboard-tube by the handheld VDG described above in **Fig. 2**.

Materials:

- Handheld VDG
- The Spinner (You may use the electroscope instead of the spinner)
- Teflon Rod
- Acrylic Rod
- Silk

Virginia SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 4.3d
Suitable for students in grades 9-12

Prediction

1. If you place an uncharged acrylic rod in the spinner, what do you think will happen if you bring the charged Van De Graaf Generator nearby? Explain.

____
____
____

2. If you rub the acrylic rod with silk and then place the charged rod on the spinner, what do you think will happen if you bring the charged Van De Graaf Generator nearby? Explain.

____
____
____

Procedure

1. Set up the spinner as shown earlier. Charge up the acrylic rod by rubbing it on silk. Place the acrylic rod on the spinner so that the center of mass falls close to the pivot. See **Fig. 6.** What is the polarity of charge on the acrylic rod when rubbed with silk? Where does acrylic lie with respect to Teflon in the triboelectric series?

____
____
____

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

Press the button on the handheld VDG to start the charge generation process. Move it towards the acrylic rod from the side as shown in **Fig. 6**. How does the acrylic rod react? What does this movement say about the polarity of the charge on the VDG?

____

____

____

Fig. 6 Spinner with charged acrylic rod

3. Remove the acrylic rod. Charge up the Teflon rod by rubbing it on silk. Place the Teflon rod on the spinner so that the center of mass falls close to the pivot. What is the polarity of charge on the Teflon rod. Where does Teflon lie with respect to silk in the triboelectric series?

____

____

____

4. Press the button on the handheld VDG to start the charge generation process. Move it towards the Teflon rod from the side. How does the Teflon rod react?
What does this movement say about the polarity of the VDG. Are you results consistent?

____

____

____

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

Activity 7-2 Electric Firefly

Overview:
The firefly consists of a mini salt and pepper partially transparent canister from Dollar Tree that. A mini electronic neon glow light bulb is placed on the inside with two wires coming out of the shaker holes on the top as shown in **Fig. 7.** One wire is connected to the anode and the other is connected to the closely spaced cathode inside the bulb. The glass also contains a low-pressure neon gas mixed with another gas that when ionized it gives off an orange light when high voltage and sufficient current is applied. It is used as an indicator light in the electronics industry or even a check engine light in your car**.** The wires are glued so that they hold the firefly suspended inside the cannister. The firefly in the class kit comes pre-assembled.

Fig. 7 A mini salt/pepper cannister with a neon gas filled bulb with wires from its anode and cathodes protruding from the holes in the top

Objective: (1) Show that that the indicator light can made to glow with the voltage from the VDG stick. (2) Show it can be made to glow with charged Teflon Rod.

Materials:

- Handheld Van de Graaff
- Teflon rod with silk cloth
- Cannister with neon bulb

Procedure (1) VDG stick:

1. Dim the lights in the room.

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

2. Turn on the VDG and hold it as close as possible to the capsule. What do you see? It should see an orange glow that comes on and then turns off. After the VDG discharges and the spark stops, the glow stops until the VDG voltage increases again until it discharges the neon bulb and the process repeats itself. If you touch one wire with your finger, it might stay on almost continuously since it requires less voltage if you provide a path for the current to flow.

Procedure (2) Teflon rod with silk cloth:

1.The charged Teflon rod does not produce as much voltage as the VDG. It requires a little more care to get a glow. Here is a reliable method to get the neon bulb to glow..
You need to get closer to the bulb itself. Unscrew the cap and remove the top and set it upside down on your table with the bulb facing upwards.

2. Now dim the lights again – maybe even more than before.

3. Rub the Teflon rod with silk to get it charged up as best as you can. Bring the rod as close as possible to the bulb. First the bulb will be attracted to the rod and then when it touches the rod the spark will occur. What do you see in the firefly capsule when the discharge occurs? The glow will occur

4. If the glow does not occur, try charging the rod up again. If the relative humidity is higher than 50%, you may not get enough charge on the Teflon rod. You may also try touching one of the protruding wires while bring the rod close to the bulb. Usually steps 1-3 work.

Questions:

1. Why does the glass bulb get attracted to the rod when you bring the rod close to the bulb?____
____
____

2. Why don't you have to take the glass bulb out of the container to get it to glow using the VDG? ____
____

3. When the spark occurs and ionizes the gas, how is the light generated? Use ideas from the atomic model of the atom____
____
____

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

Activity 7-3: Electric Levitation

Objective: Levitate thin conductive strips by means of electric repulsion.

Materials:

- Thin conductive strips or pieces of thin foils provided. You may use any of the provided shapes in the booklet
- Handheld VDG

Procedure:

1. Unfold the band-shaped conductive strip and hold it in one hand. Use the handheld VDG to generate charge. Release the strip and touch it with the handheld VDG. **Fig. 8** is an illustration of a successfully charged strip. What shape does the strip turn into? What does this have to do with static electricity?

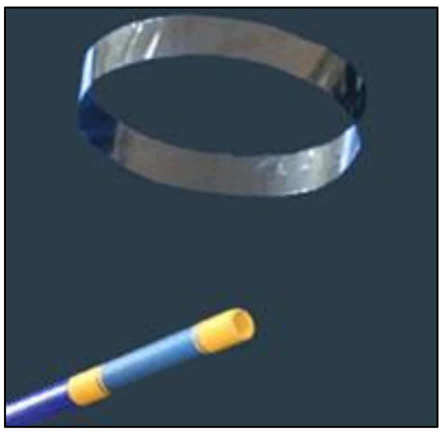

Fig. 8 Levitating circular charged conducting strip

2. Keep the handheld VDG underneath the strip to levitate the strip. Some people might claim the handheld VDG produces a shield against gravity. Is that true? What keeps the strip from falling to the ground?

____

____

____

3. Reach your palm towards the strip but don't get too close. How does the strip respond to your "beckoning hand"? Why?

____

____

____

4. Now touch the strip with your hand. What shape does the strip turn into? Why?

____

____

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

Activity 7-4: Faraday Cage

Introduction:
A metal wire mesh screen that is connected to ground can be used to prevent an electric field from permeating through the space behind it. If the screen surrounds some space entirely, then anything inside feels no electric field from the outside, even if the screen is not grounded any more. The Faraday Cage consists of such a screen that closes upon itself to provide shielding from any electric field outside the cage. A common example of a Faraday Cage is an elevator. Cell phone signals are blocked inside the elevator unless a relay antenna is installed. A metal car could also be a Faraday cage if it weren't for the windows. A wire mesh screen also acts as a Faraday cage even though it it has small holes in it. A microwave has such a screen and is used to block the microwaves from coming through the glass window.

Objective: Demonstrate the shielding effect of a wire mesh screen.

Materials:

- Handheld Van de Graaff
- Wire Mesh Screen
- Electroscope (you may use the spinner and a charged Teflon rod instead of the electroscope)

Procedure:
1. Neutralize the electroscope by touching the brass support with your finger. The tube should be at a negligible angle against the brass support.

2.Turn on the handheld VDG and move its front end to about 5-10 cm away from the electroscope. See **Fig. 9** for the geometry. How does the tube behave when the charged VDG approaches it?
____
____
____

Fig. 9 Charged VDG is held near the electroscope tube but not touching.

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

3. Turn off the handheld VDG and neutralize the electroscope again. Now, hold up the wire mesh screen about 5 cm in front of the electroscope. Make sure your fingers are in contact with the metal part of the screen. Then repeat step 2. See **Fig. 4**. How does the tube behave this time? What makes the difference and why? (Hint: Recall the activities on "charge by induction/polarization at the beginning of Activity 6")

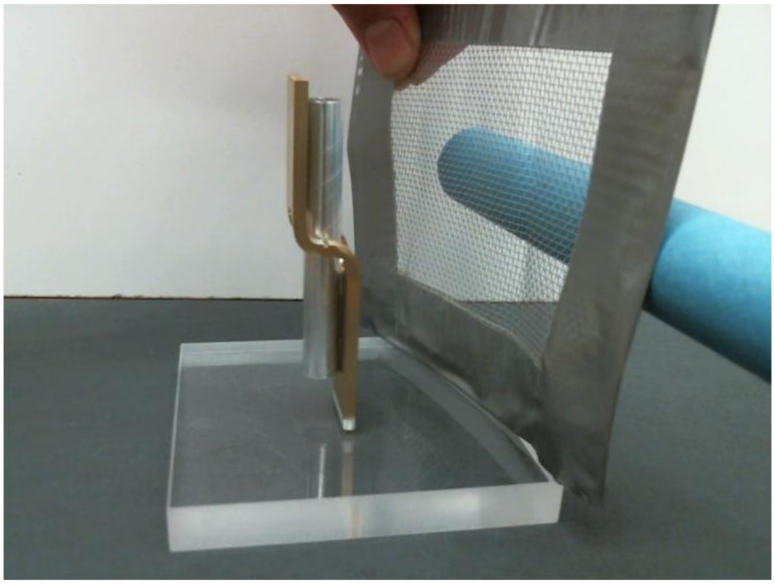

Fig. 10

4. If the mesh screen were made from an insulating material, would it still act as a Faraday cage?

Explain.____

____

____

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership

Activity 7-5: Flying Saucer

Objective: Observe the strength of static electricity compared to gravity.

Materials:

- Handheld VDG
- Small Pie Tins x 5 (from home or Dollar Tree)

Procedure:

1. Get 5 small pie tins that are used to make mini tarts. Hold the handheld VDG pointing straight up. Stack the pie tins upside-down on the tip of the handheld VDG

2. Press the button on the handheld VDG to start the charge generation process. Describe the reaction of the pie tins.

____
____
____

3. What causes the pie tins to fly off as in **Fig. 11**? Describe the role of static electricity in the takeoff process

____
____

Fig. 11 The handheld VDG is shown blowing the pie tins upward

Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership