VAN DE GRAAFF GENERATOR

CAT NO. EDU VDG

Experiment Guide

GENERAL BACKGROUND:

The van de Graaff generator is a simple device designed to create large voltages with low current. It can be used to dynamically demonstrate several physical concepts, including: electrostatics, conservation of charge, conduction, and ionization.

Static electricity is a familiar concept we encounter on a daily basis. It explains: why static cling affects our clothes, the shock we sometimes experience when touching a doorknob on a dry winter day, and why we can cause a friend's hair to stand on end by "charging up" a balloon.

Charge Conservation and Transfer

Charge is an intrinsic (natural) property of particles. Charges can be positive, negative, or neutral. When two charges have opposite signs (positive and negative), they are attracted to one another. When two charges have the same sign (both negative or both positive), they are repelled. Within any material there are both positive and negative charges, and how the material behaves depends on whether there are more positive charges, more negative charges, or an equal number of both (neutral object). The total charge in the universe is always conserved-- we cannot create new charges or destroy existing ones. Charge can, however, be transferred between objects. Conduction is one process by which a charged object transfers charge to another object through contact.

Triboelectric Effect ("Charging by Friction")

Most static electric phenomena are due to the triboelectric effect, which affects both conductors and insulators. In this effect two neutral objects touch or are rubbed together so that electrons can pass between them. Some objects give up electrons easily and others hold on to them tightly. The triboelectric scale is used to rate the natural tendency of materials to give up electrons: objects that lose electrons easily are "positive," those that hold on to them tightly are "negative." Notice that this property is not the same as conductivity, which measures how easily electrons move within a given object. When amber (negative on the triboelectric scale) is rubbed with a piece of wool (positive on the triboelectric scale), the wool gives some of its electrons to the amber and both emerge with a net charge.

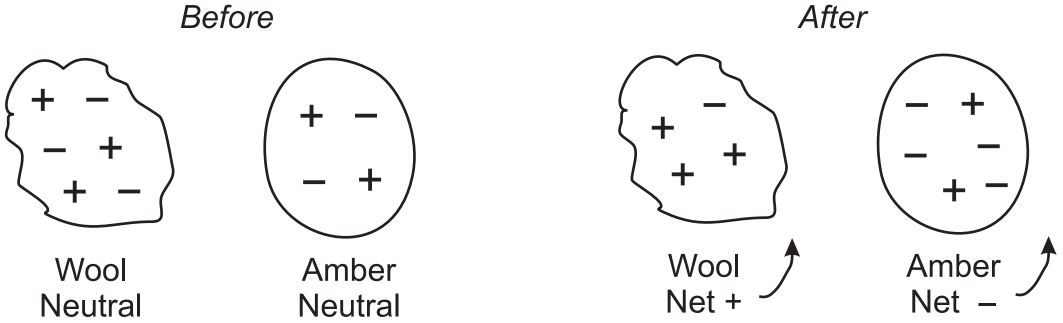


Diagram 1

Notice that charge is merely exchanged between the amber and wool and that the total charge stays the same. When objects acquire charge in this way, they can then “cling” to other objects (attracting them with their charge), or discharge onto another object (like after you acquire a net charge from the carpet and discharge it on a nearby doorknob or an unsuspecting friend).

Conductors and Insulators

Atoms are made of a nucleus formed from protons (positive charge) and neutrons (neutral charge) surrounded by orbiting electrons (negative charge). Most materials have an equal number of protons and electrons and are electrically neutral. When electrons are not tied to the nucleus (or are loosely bound), they may move through the material. How easily they can move from one end to the other depends on whether the material is an insulator or conductor. In conductors, electrons can move freely, whereas in insulators they cannot.

Ionization

The van de Graaff generator also demonstrates ionization of air. Ionization occurs when the electric field strength becomes strong enough to strip electrons from atoms in the surrounding air. When the electrons recombine with the positive ions in new combinations, visible light is released.

How the van de Graaff Generator Accumulates Charge

The van de Graaff generator uses an insulating belt turning on two rollers to carry charges from the bottom of the apparatus to the top and deposit them on the collecting dome.

As the lower roller is turned by the motor charges between the roller and the belt begin to be transfer due to the triboelectric effect. The roller steals electrons from the belt and so the roller acquires a net negative charge while the belt acquires a net positive charge. The concentrated negative charges on the stationary roller repel negatively charged electrons on the brush (mesh metal square), leaving positive charges near the brush tips.

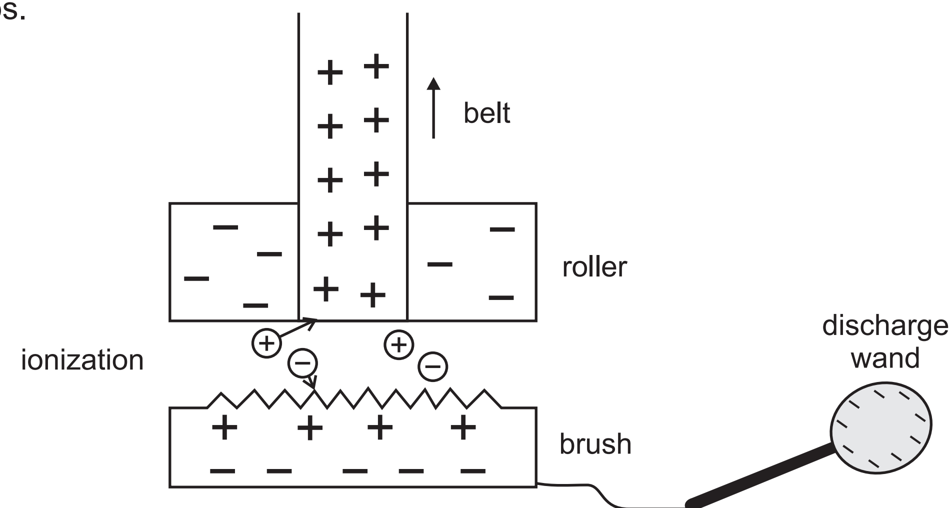


Diagram 2

Bottom Roller

The electric field created from the negative charges on the stationary (but rotating) roller ionizes the air between the brush and roller, creating positive ions and free electrons. The positively charged ions are drawn toward the negatively charged roller, but run into the insulating belt on their way towards it and get attached to the insulating belt. The belt therefore now has a supply of positive charges that it carries to the top of the apparatus. When the discharge wand is connected to the bottom of the apparatus, negative charges from the ionized air are collected by the discharge metal mesh and try to move as far away from each other as possible, spreading out over the discharge wand if allowed.

Top Roller

At the top of the apparatus there is another roller and brush and a similar process occurs. The positive charges carried up the belt attract electrons in the top brush. The electric field ionizes the air between the brush and the roller/belt. The positively charged ions are repelled by the positive charges on the belt and attracted to the electrons near the tip of the brush. The conducting collecting sphere is connected to the top metal brush and collects the accumulating positive charge.

Charges are also transferred between the top roller and brush due to the triboelectric effect. Whether the roller gains a positive or negative charge depends on the material properties of the top roller. The free electrons in the ionized air are attracted to the positive charges on the belt and, depending on whether the roller has a positive or negative net charge, this effect can be enhanced. As the belt returns to the bottom it carries either no charge or a net negative charge, depending on the material properties of the roller.

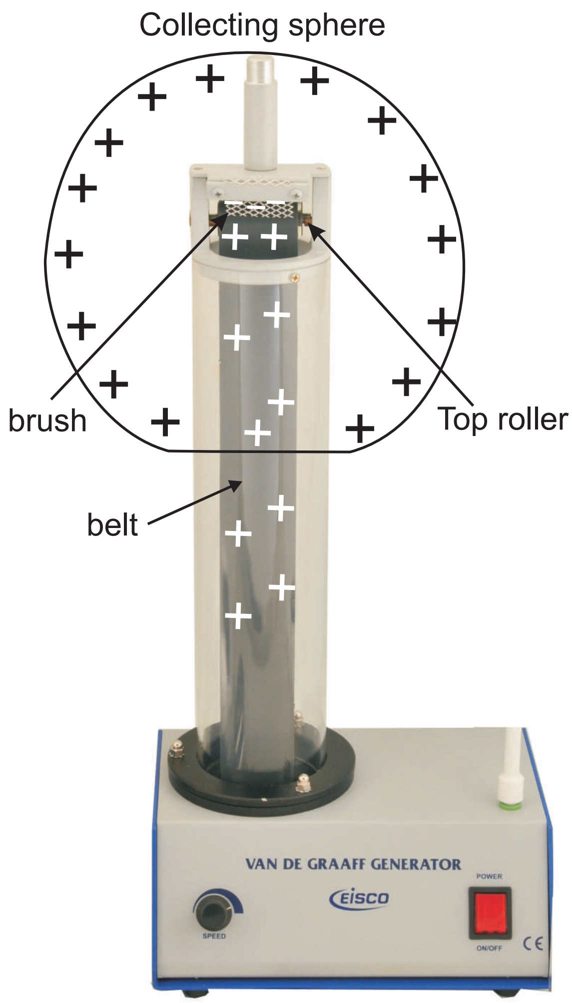


Diagram 3

Charge Accumulation and Discharge

As the belt is driven, the apparatus continues accumulating charges onto the collecting sphere until a surface maximum is reached. When this occurs, the high voltage from the charged conductor breaks down the air surrounding the top of the device. The conductor will discharges through any nearby object. When the discharge wand is brought near the collecting sphere, the conductor discharges and a small “lightning” strike can be observed. As the device discharges, it ionizes the surrounding air, stripping air atoms of their free electrons. Unlike at the bottom and top of the van de Graaff generator, though, here we do not transport the separated charges away and the electric field is much stronger. They can therefore recombine and, when they do, emit the light we observe.

Standards: (Taken from the May 2012 draft of the Next Generation Science Standards)

3.IF Interaction of Forces E) Investigate the push-and-pull forces between objects not in contact with one another.

4. E Energy B) Carry out investigations to provide evidence that energy is transferred from place to place by sound, light, heat, electric currents, interacting magnets and moving or colliding objects.

MS.PS-IF Interactions of Forces

a) Plan and carry out investigations to illustrate the factors that affect the strength of electric and magnetic forces. [Clarification Statement : Investigations can include observing the electric force produced between two charged objects at different distances and measuring the magnetic force produced by an electromagnet with a varying number of wire turns, number or size of dry cells, or size of iron core.] [Assessment Boundary : Qualitative, not quantitative; no assessment of Coulomb’s law]

b) Plan and carry out investigations to demonstrate that some forces act at a distance through fields. [Assessment Boundary : Fields included are limited to gravitational, electric and magnetic. Determination of fields are qualitative, not quantitative (e.g. forces between two human-scale objects are too small to measure without sensitive instrumentation.)]

REQUIRED COMPONENT (INCLUDED)

Name of Part	*Quantity*
Assembled base (rollers, belt, brushes)	1
Large metal dome	1
Discharge wand	1
Wrench	1
Dancing Balls Accessory	1
Extra Band	1
Spiked Arm Wheel	1
Oscillating Pith Ball	1
Plastic Comb	1
Neon Tester	1
Electrical Cord	1
Brush of Long Hairs	1

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Puffed cereal or styrofoam peanuts	1 cup
Plastic bowl	1
Metal bowl/can/ladle	1
Balloon	1
Paper, tape, cheerleading pom-pom	1
Alligator clip wire	1
Banana plug wire	1

SAFE HANDLING OF APPARATUS:

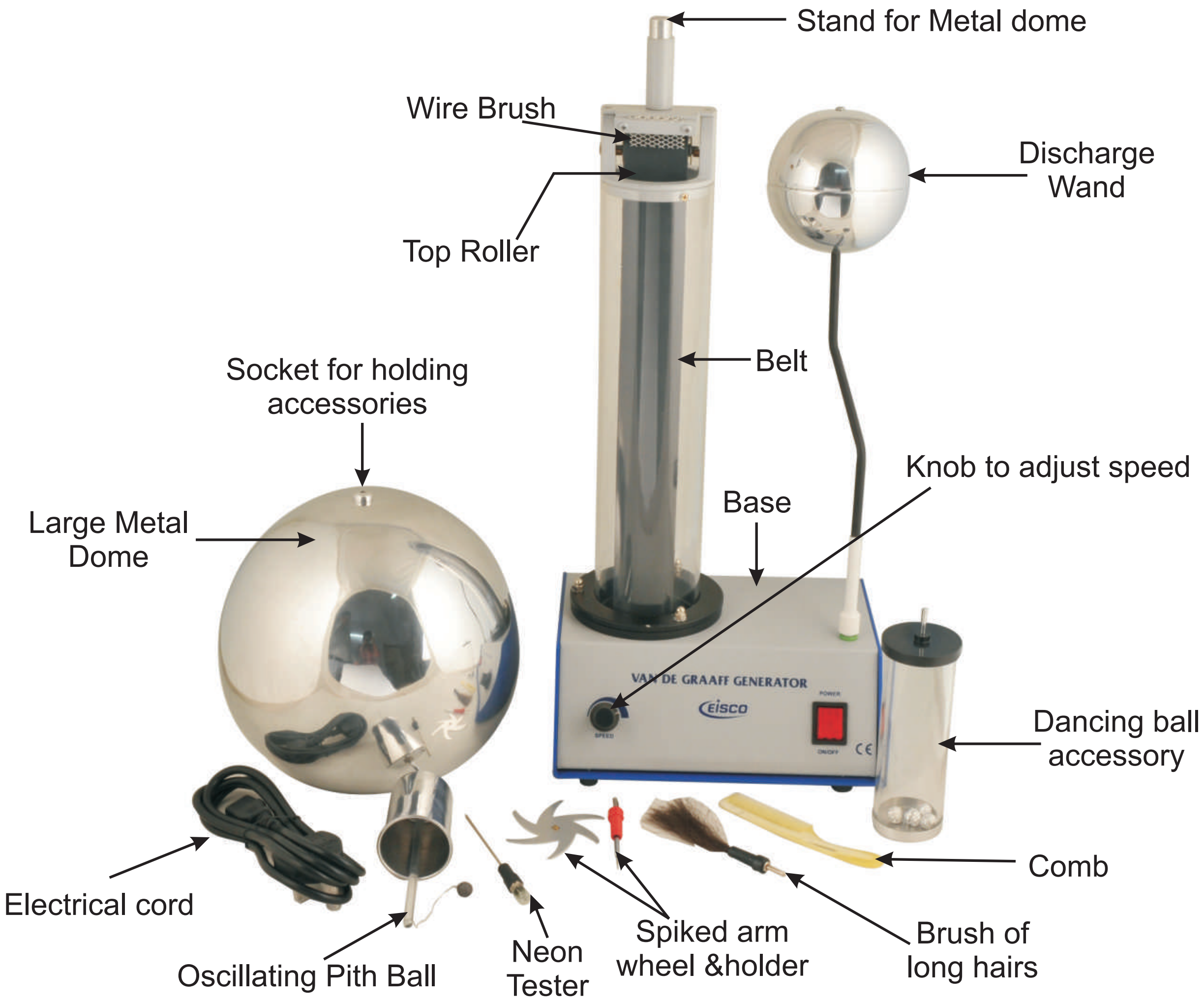
Warning: Persons with cardiac pacemakers should never operate the van de Graaff generator.

Do not run the device near operating computer or electronic equipment.

The van de Graaff generator is designed to produce high voltages using currents too low to cause serious injury. However, always exercise caution when using the generator to avoid painful or surprising sparks.

Always discharge the device between demonstrations using the included discharge wand.

DO NOT USE with Leyden jars to avoid injury.



MAINTENANCE AND CARE:

Store the generator in a dry, dust-free environment under a polythene cover. Keep the device dry even on wet, humid days.

To prolong the life of the belt, run the generator for only short periods of time and ensure that the brushes are not in direct contact with the belt.

Brush Adjustments:

If needed, the top and bottom aluminum mesh brushes can be adjusted. Simply loosen the two screws on the bracket, slide the brush to adjust, and retighten the screws. Always leave some space between the brush and the belt.

Band Replacement:

Replacement belts can be ordered from the dealer and should be installed by qualified persons. When replacing the belt, take care not to bend the bottom brush. There is a band that is designed to wear out before the brush. An extra band is included with your van de Graaff. Here is how to replace the band.

1. Remove the collecting sphere from the top of the apparatus and set aside. Unplug the discharge wand and remove base cover of van de Graaff by removing the screws in the four rubber feet at the bottom of the base as shown in diagram 4.

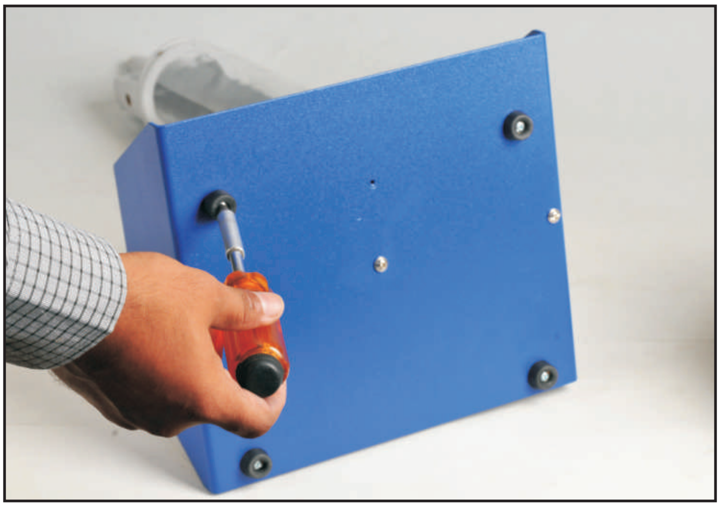


Diagram 4

2. Do not remove the metal screws as those are holding posts to support the weight of the apparatus in place.

3. Inside next to the motor is a small band that is designed to break before the belt does. To replace this belt simply remove the old belt and slide the new belt on as shown in diagram 5.

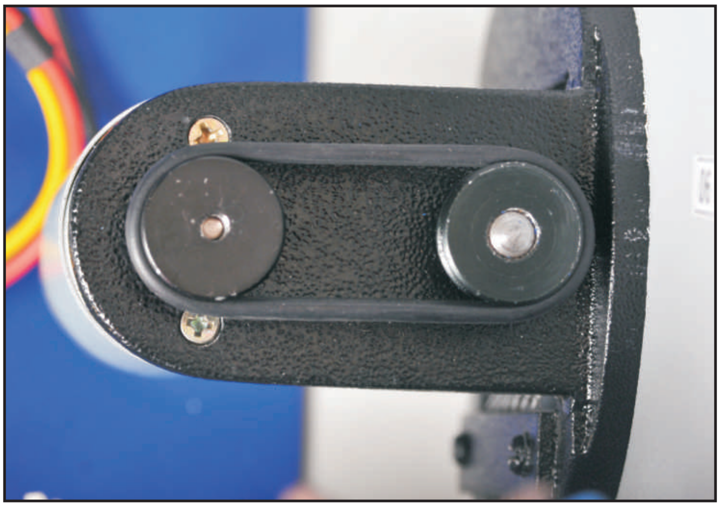


Diagram 5

Cleaning:

The van de Graaff generator should be lightly dusted regularly with a clean, dry cloth. Occasionally, it may be necessary to use a small amount of a methylated spirit to clean the collector dome and top brush. For the dome, remove it from the apparatus before wiping with a clean cloth and small amount of solvent. Be sure that the solvent evaporates before replacing the dome onto the apparatus. To clean the top brush, remove it by unscrewing the screws and be sure the solvent evaporates before reinstalling. As always when replacing the brush, position it so that there is a small air gap between the brush and the belt.

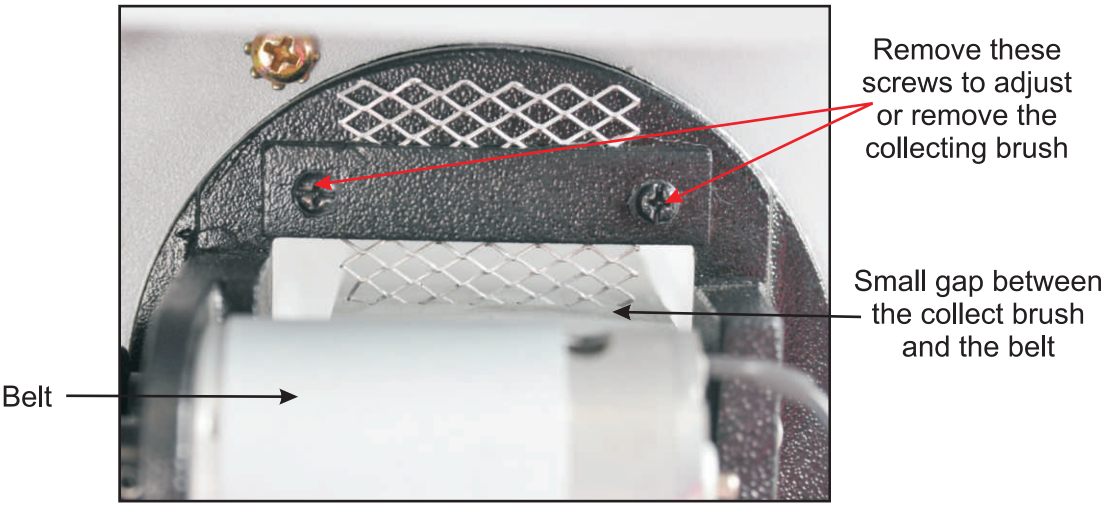


Diagram 6

ACTIVITY 1: CHARGING THE VAN DE GRAAFF (TEACHER ANSWERS)

Van de Graaf generators use an insulating belt to carry charge from the bottom to the top of the apparatus and disperse charge on a collecting sphere. In this short exercise, students will determine whether the accumulated charge is positive or negative and illustrate the basic method of how the device charges. Students will charge two objects by rubbing them together (using the triboelectric effect) and, given the charge of the objects they have used, determine the charge accumulated on the van de Graaff generator sphere.

Neon Bulb Tester

Wool sock (positive) plastic comb (negative)

Hair (positive) and Balloon (negative)

PROCEDURE:

1. Rotate the discharge wand away from the collecting dome.
2. Turn the generator on for about 2-3 seconds and then turn it off.
3. Bring the metal point of the neon bulb tester to the top of the dome and touch the dome while holding onto only the plastic part of the neon tester.
4. Observe whether the large top filament or the smaller bottom filament is illuminated.

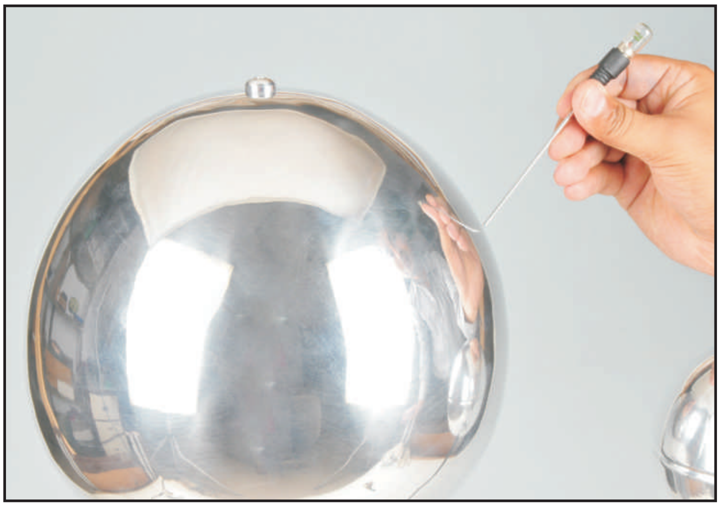


Diagram 7

Diagram 8

Diagram 8 is an up close view of the neon tester, There are two discs inside the bulb. If the top one illuminates, then the charge on the object was positive, if the bottom one illuminates, then the charge was negative.

DATA ANALYSIS:

1. Was the charge on the metal dome positive or negative? Justify your answer.
   (Positive, because the top filament illuminated)

2. Now pick two objects to rub together. As the two objects are rubbed together, one will acquire a positive charge and one will acquire a negative charge. Bring both objects towards the charged van de Graaff, without touching and without a static discharge, and record your results below.
   (The hair rubbed with the balloon caused the balloon to attract to the dome of the van de Graaff, the wool sock repelled from the collecting dome after rubbing the comb.)

3. Using your results, determine the charge on each object. Justify your result.
   (The charge before both objects were rubbed together is neutral, since charge cannot be created or destroyed, if the charge on one object is positive, the charge on the other object must be negative. Like charges repel and opposite charges attract. Since the balloon was attracted to the van de Graaff, then the balloon must be negatively charged and the hair must therefore be positive. It is important to note here that a neutral object will attract to a charged object. If the teacher has already discussed this concept with the students, then the only single test for charge on an object is repelling. Therefore we know for sure that the charge on both the van de Graaff and the wool sock is positive because the two objects repelled.)

4. Draw a picture of each of your two objects before they were rubbed together and after they were rubbed together. Use "+" to represent positive charges and "-" to represent negative charges. Draw six "+" and "-" in your before and after picture to represent the net charge on your objects.

Before

After

Name:____ Date:____________

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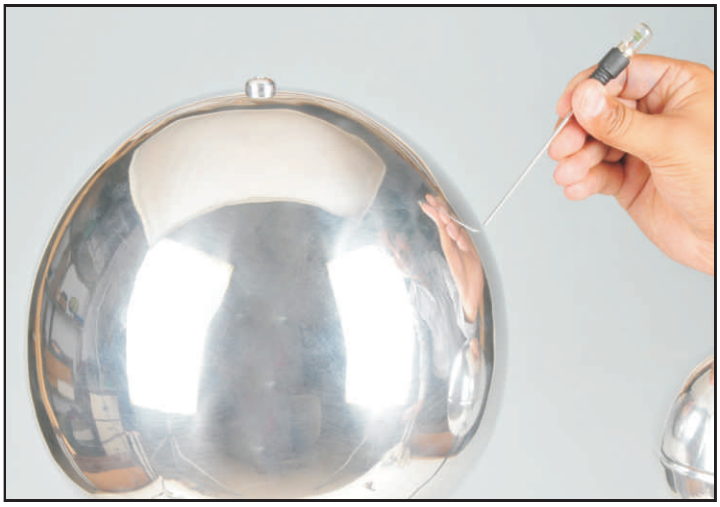

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Before After

ACTIVITY 2: LIGHTENING IN THE LABORATORY (TEACHER ANSWERS)

PROCEDURE:

1. Connect the discharge wand to the generator and move it away from the collecting dome.
2. Begin charging the generator by turning the switch on.
3. Slowly move the discharge wand closer to the collecting sphere.
4. Hold the wand close to (but not touching the sphere). Then move the wand a few inches back (but still close enough for "lightning" to occur). Note any differences you observe.
5. Next increase the rate that the belt rotates by turning the speed knob clockwise.

DATA/OBSERVATIONS:

What did you observe as the discharge wand approached the collecting sphere?

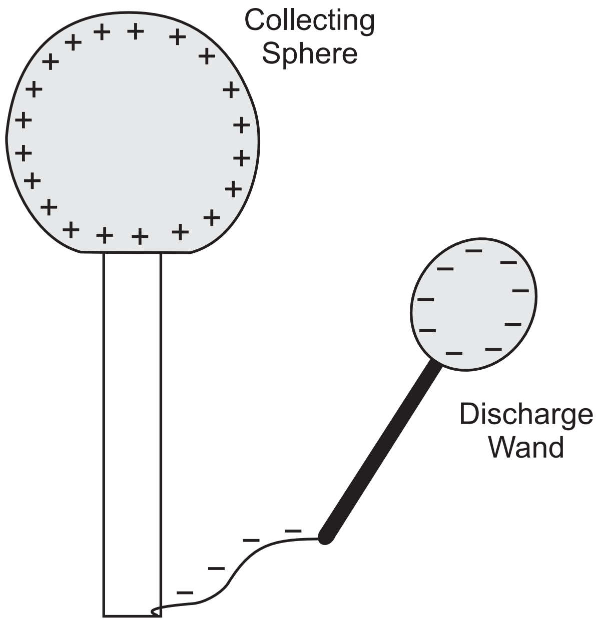
(As the wand got closer, the blue spark jumped between the dome and the wand, the spark jumped more often if the two were close, the bolt increased in length and decreased in frequency as the wand got further from the van de Graaff, until it reached a point where the spark would not form anymore.)

What happened as the speed was increased?

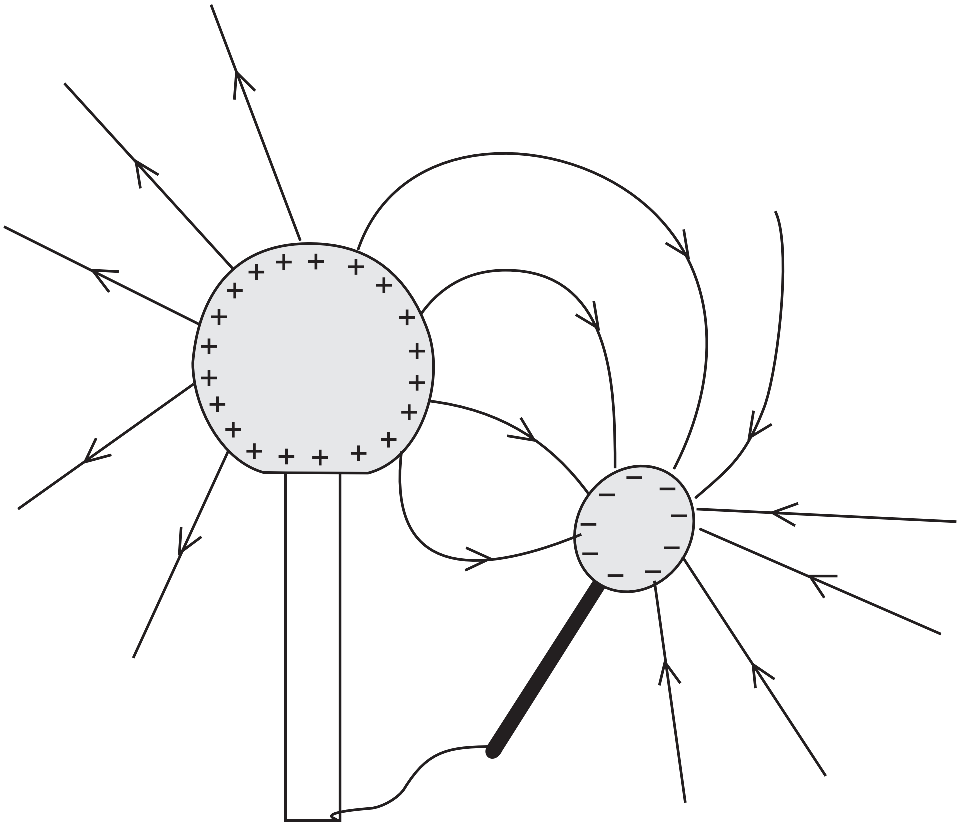
(As the speed increased, the frequency of the sparks increased.)

FOLLOW UP QUESTIONS:

1. Use at least five "+" to indicate where on the van de Graaff the net positive charge is accumulated on the sphere and use at least five "-" to indicate where the net negative charge is accumulated on the Van de Graaff.



2. Draw at least five electric field lines and indicate the direction of these lines with an arrow in question 1 you drew above. (Give students credit for any field lines that go out of positive charge and into negative charge.)



3. Ionizing the air requires some amount of energy. Where did the energy come from? State what types of energy there are and where they come from.
The electrical energy from the wall plug is converted into mechanical energy used to rotate the motor, which in turn is converted to electrical energy when the charges are separated.

4. If the charges discharge and the electrical field is gone, where does the energy go?
The total energy is conserved, but it is converted into less useful forms of energy - like friction, heat, and sound. Some of the mechanical energy is lost to friction in the device, some is lost to heat and sound (like the crackle we hear when the sphere discharges).

Name:____ Date:_____________

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What did you observe as the discharge wand approached the collecting sphere?

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FOLLOW UP QUESTIONS:

1. Use at least five “+” to indicate where on the van de Graaff the net positive charge is accumulated on the sphere and use at least five “-“ to indicate where the net negative charge is accumulated on the van de Graaff.

2. Draw at least five electric field lines and indicate the direction of these lines with an arrow in question 1 you drew above.

3. Ionizing the air requires some amount of energy. Where did the energy come from? State what types of energy there are and where they come from.

4. If the charges discharge and the electrical field is gone, where does the energy go?

ACTIVITY 3: SNAKE CHARMING
(TEACHER ANSWERS)

Charged objects can attract charge and even neutral materials by exerting a force on the electrons within the material. In the activity below, see if you can control the motion of a strip of uncharged paper without touching it.

PROCEDURE:

1. Place a few small (1” wide) strips of paper on the table near the van de Graaff generator.
2. Plug a banana clip wire in where the discharge wand goes, and then connect the end of the discharge wand to the free end of the banana plug wire using an alligator clip wire.
3. Charge the generator by turning the apparatus on for 10-15 seconds.
4. Move the discharge wand above the strips of paper. Try wiggling the wand from side to side and up and down. Note your observations below.
5. Discharge the collecting globe by touching it with the discharge wand.

DATA/OBSERVATIONS:

What did you observe while the wand hovered above the strips of paper?

One end of the paper lifted off the table toward the wand. The strip danced around as the wand moved.

FOLLOW UP QUESTIONS:

What is the net charge on the paper before the wand is charged?

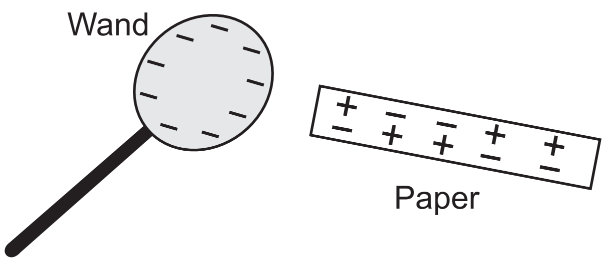
The paper is electrically neutral, it has an equal number of electrons and protons.

What is the net charge on the paper after the wand is charged?

The paper stays electrically neutral. The wand never touches the paper and no charge is transferred.

Draw a diagram below to show how the charges in the paper are distributed before and after the wand is charged (assume the wand has a net negative charge).

Before



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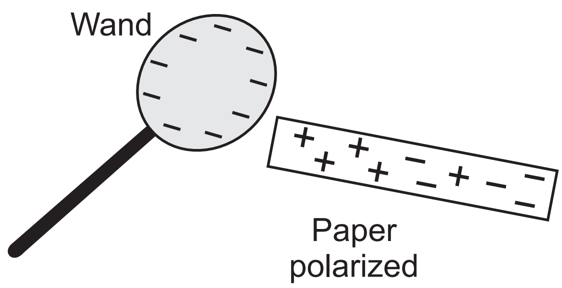

Technically the electrons don't really move from one side of the paper to the other, but shift from one side of the atom to the other creating a positive side of the atom and a negative side of the atom, but for student's conceptual understanding, the diagram above will suffice.

Use your diagram to explain how the wand can “control” (attract/repel) the paper if the paper has no net charge.

The negative charge on the wand repels the electrons in the paper and attracts the positive ions or protons. This induced polarization means that the paper acts as though there is a net positive charge at one end (near the wand) and a net negative charge at the other (near the table). The positive end of the paper attracts the wand and they move toward each other.

Name:______________________________________ Date:____________

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DATA/OBSERVATIONS:

What did you observe while the wand hovered above the strips of paper?

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FOLLOW UP QUESTIONS:

What is the net charge on the paper before the wand is charged?

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What is the net charge on the paper after the wand is charged?

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Draw a diagram below to show how the charges in the paper are distributed before and after the wand is charged (assume the wand has a net negative charge).

Before *After*

Use your diagram to explain how the wand can "control" (attract/repel) the paper if the paper has no net charge.

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ACTIVITY 4: "OBSERVING" ELECTRIC FIELD LINES

(TEACHER ANSWERS)

A charged object produces an electric field that we can represent with field lines. These lines tell us which direction a test charge will travel when influenced by the electric field. In the following activities, we will "see" the field lines by observing how they cause other materials to behave.

A) Field Lines on the Globe

PROCEDURE:

1. Tear paper into 8-12 thin strips (about 1/2" wide and 6 inches long). Attach the strips to the globe with tape, trying to distribute them evenly, or attach the brush of long hairs to the slot on top of the Van de Graaff as show in diagram 10.

Diagram 10

2. Charge the van de Graaff generator for 10-20 seconds and make sure the discharge wand is not touching the collecting dome.

DATA/OBSERVATIONS:

What happened to the paper strips or brush of long hairs as the globe acquired charge? Draw a picture of what you saw. (Should look like diagram 10)

<u>The paper strips stood out in all directions on the globe.</u>

FOLLOW UP QUESTIONS :

1. What was the charge of the paper (or hair) before the van de Graaff was turned on?

   The material was electrically neutral. It had an equal number of positive and negative charges.

2. What was the charge of the paper after the van de Graaff was charged? Did it acquire the charge through conduction or induction? Justify your response.

   It gained a net positive charge from the van de Graaff sphere. The charge was transferred by contact/conduction. Each strip followed the electric field lines produced by the globe, just like test charges placed in an electric field. Each strip had a net positive charge, because when a charge object transfers charge to another object by coming in contact with it, the charge on both objects is the same.

B) Hair-Raising Field Lines

In this classic demonstration of the van de Graaff generator, a student volunteer stands on an insulating surface and places one hand flat on the top of the collecting sphere. It helps if the student gently shakes his or her head from side to side as charges accumulate. As long as nothing comes close to the student to discharge him or her, they should not receive a shock. Charging the van de Graaff generator produces some hair-raising results.

1. What was the charge of the volunteer's hair before the van de Graaff was turned on?

   The hair was electrically neutral. It had an equal number of positive and negative charges.

2. What was the net charge of the volunteer after the van de Graaff was charged?

   He/she gained a net positive charge from the van de Graaff sphere.

3. Why is it important for the volunteer to stand on an insulating surface?

   The insulating surface prevents the charges from going straight into the ground. If that happens the hair will never acquire a positive charge.

4. Where does the charge go after the student stops turning the hand-crank?

   Some of it leaks to ground (through the volunteer's feet), some is lost to the air, and some of it stays on the generator (until it is discharged with the wand).

Name:____ Date:______________

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A) Field Lines on the Globe

PROCEDURE:

1. Tear paper into 8-12 thin strips (about 1/2" wide and 6 inches long). Attach the strips to the globe with tape, trying to distribute them evenly, or attach the long hairs to the top of the collecting sphere with tape. Draw a picture of what you see in the space provided below.

Diagram 10

2. Charge the van de Graaff generator and note your observations below.

DATA/OBSERVATIONS:

What happened to the paper strips or hair as the globe acquired charge and the voltage grew? Draw a picture of what you saw.

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FOLLOW UP QUESTIONS :

1. What was the charge of the paper or hair before the van de Graaff was turned on?

2. What was the charge of the paper or hair after the van de Graaff was charged? Did it acquire the charge through conduction or induction? Justify your response.

B) Hair-Raising Field Lines

In this classic demonstration of the van de Graaff generator, a student volunteer stands on an insulating surface and places one hand on the collecting sphere. Charging the van de Graaff generator produces some hair-raising results.

FOLLOW UP QUESTIONS :

1. What was the charge of the volunteer's hair before the van de Graaff was turned on?

2. What was the net charge of the volunteer after the van de Graaff was charged?

3. Why is it important for the volunteer to stand on an insulating surface?

4. Where does the charge go after the student stops turning the hand-crank?

ACTIVITY 5: CONDUCTORS AND INSULATORS (TEACHER ANSWERS)

In this activity, students can compare the behavior of insulators and conductors in the presence of electric fields and charges.

A) Conductors: Flying plates

PROCEDURE:

1. Tape a pie plate to the top of the globe. Place 3-4 more untapped pie plates on top of it. (If pie plates are unavailable, squares of aluminum foil can be used)
2. Charge the van de Graaff generator making sure the discharge wand is not touching the van de Graaff. Observe the behavior of the pie plates.
3. After the demonstration, discharge the globe by touching it with the discharge wand.

DATA/OBSERVATIONS:

The top pie plate flew up and off, then the next one went, and the next until they were all gone.

FOLLOW UP QUESTIONS:

1. Was charge transferred to the pie plates? If so, was this an example of conduction or induction?

   Yes, each pie plate acquired positive charge through conduction (by touching the plate below it).

2. What caused the pie plates to "fly away" from the van de Graaff generator?

   Each plate has the same charge (positive). Since like charges repel, the top plate was repelled. Charge inside a conductor is always neutral, since the pie plates in the middle of the stack are considered to be inside the conductor, they have a neutral charge until they become the top plate.

B) Leaky Insulators: Peanuts, Popcorn!

PROCEDURE:

1. Place some puffed cereal, packing peanuts, or popcorn inside of a glass or plastic bowl.
2. Balance or tape the partially filled bowl on top of the van de Graaff globe.
3. Charge the van de Graaff generator.
4. After the demonstration, discharge the globe.

DATA/OBSERVATIONS:

What did you observe when the generator become charged?

The popcorn flew off in all directions from out of the bowl.

FOLLOW UP QUESTIONS:

1. What can you say about the charge of the peanuts/popcorn/cereal pieces before and while the van de Graaff was charged?

   The filling was originally electrically neutral. When the van de Graaff became charged, the charge transferred to the filling pieces and they flew away from one another because like charges repel.

2. If the bowl is made out of "insulating" material (glass or plastic), how was charge transferred to the peanuts/popcorn/cereal?

   Through conduction. Even though glass/plastic are insulators, they are not perfect insulators. Some of the electrons move a little and when the charge from the van de Graaff gets strong enough, charge can travel through the glass/plastic and transfer to the filling.

Teacher's note: If students are unconvinced that charge leaks through the plastic/glass, repeat the demonstration holding the bowl close to (but not touching!) the top of the globe. None of the filling should fly out of the bowl.

C) Quality Conductors: Peanuts, Popcorn!

PROCEDURE:

1. Repeat the experiment above, but place the filling inside of a metal bowl or container Even a soup ladle also works remarkably well.

DATA/OBSERVATIONS:

What did you observe when the generator become charged?

(Nothing happened. The popcorn stayed in the bowl or only a tiny amount flew out)

FOLLOW UP QUESTIONS:

1. What can you say about the charge of the peanuts/popcorn/cereal pieces before and while the van de Graaff was charged?

   (They started and remained neutral. No charge was transferred.)

2. How does using a container that easily conducts electricity as opposed to an insulating container change the results of the experiment?

   (Charge moves easily in a conductor and distributes itself on the surface of the container. The charges move away from each other as much as possible and, as a result, the electric field inside of a conductor is zero. Since the electric field inside of the metal bowl must be zero, the filling never acquires charge and remains electrically neutral.)

Name:____ Date:______________

ACTIVITY 5: CONDUCTORS AND INSULATORS

In this activity, students can compare the behavior of insulators and conductors in the presence of electric fields and charges.

A) Conductors: Flying plates

PROCEDURE:

1. Tape a pie plate to the top of the globe. Place 3-4 more pie plates on top of it. (if pie plates are unavailable, squares of aluminum foil can be used)
2. Charge the van de Graaff generator. Observe the behavior of the pie plates.
3. After the demonstration, discharge the globe.

DATA/OBSERVATIONS:

What did you observe when the generator become charged and the voltage grew?

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FOLLOW UP QUESTIONS:

Was charge transferred to the pie plates? By what physical process?

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What caused the pie plates to “fly away” from the van de Graaff generator?

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B) Leaky Insulators: Peanuts, Popcorn!

PROCEDURE:

1. Place some puffed cereal, packing peanuts, or popcorn inside of a glass or plastic bowl.
2. Balance or tape the partially filled bowl on top of the van de Graaff globe.
3. Charge the van de Graaff generator.
4. After the demonstration, discharge the globe.

DATA/OBSERVATIONS:

What did you observe when the generator become charged and the voltage grew?

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FOLLOW UP QUESTIONS:

What can you say about the charge of the peanuts/popcorn/cereal pieces before and while the van de Graaff was charged?

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If the bowl is made out of "insulating" material (glass or plastic), how was charge transferred to the peanuts/popcorn/cereal?

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C) Quality Conductors: Peanuts, Popcorn!

PROCEDURE:

1. Repeat the experiment above, but place the filling inside of a metal bowl or container (even a soup ladle also works remarkably well).

FOLLOW UP QUESTIONS:

What did you observe when the generator become charged and the voltage grew?

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CONCLUSIONS:

What can you say about the charge of the peanuts/popcorn/cereal pieces before and while the van de Graaff was charged?

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If a conductor transfers charge easily, why don't the peanuts/popcorn/cereal gain charge through conduction and fly off?

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ACTIVITY 6: DANCING BALLS ACCESSORY (TEACHER ANSWERS)

PROCEDURE:

1. Set up the apparatus as shown in diagram 11.
2. Move the discharge wand as far away from the collecting sphere as possible.
3. Turn on the van de Graaff for 10-15 seconds and observe what happens to the aluminum balls.

Diagram 11

OBSERVATIONS:

(Slowly at first and then rapidly, the aluminum balls inside the tube rise up and then fall back down. Eventually they come to rest somewhere in the middle of the tube while the van de Graaff is charging.)

QUESTIONS:

1. What is the charge on the aluminum balls before the van de Graaff is turned on? Justify your answer.

   (Before the van de Graaff is turned on, the balls are neutral because they neither attract nor repel other objects near them.)

2. Using your knowledge of conduction and induction, what do you think the charge is on the aluminum balls soon after the van de Graaff is turned on but before the balls touch the top of the tube? Justify your answer using conduction or induction in your response.

   (The aluminum balls must be positively charged because they are repelled from the top of the van de Graaff and like charges repel. There is a metal path from the top of the van de Graaff to the aluminum balls which are also metal, therefore, the aluminum balls are charged by conduction.)

3. What is the charge on the top of the tube after the balls hit the top of the tube?

Justify your response using the term conduction or induction.
(The metal balls hit the top of the tube and transfer their charge by conduction, so top of the tube acquires a net positive charge.)

4. Explain why the metal balls come to rest in the middle of the tube in terms of charge.
(The charge on the bottom of the tube, the top of the tube and the aluminum balls are all positive. Like charges repel. Therefore the aluminum balls are repelled by the top of the tube and the bottom of the tube, so they come to rest in the middle of the tube.)

PROCEDURE CONTINUED:

4. Place your finger on the metal top of the tube and leave it there.
Record your observations:
(The metal balls will rise to the top and the return to the bottom of the tube over and over again.)

QUESTIONS:

1. When you touch the top of the tube, what happens to the positive charge on top of the tube?
(Your finger acts like a ground, touching the top allows negative charges to enter the top of the tube and become either neutral or negatively charged.)

2. What happens to the charge on the metal balls when they touch the top of the tube?
(The metal balls also become neutral or negatively charged as they touch the top. They are therefore attracted to the positively charged bottom of the tube.)

3. What happens to the charge of the metal balls as they touch the bottom of the tube after touching the top? Explain in terms of charge, why the balls rise from the bottom again.
(When the balls reach the bottom, they acquire a positive charge again through conduction and therefore repel the positive dome and rise to the top of the tube and the process repeats itself.)

4. What happens after all the charge is gone from the metal dome on the van de Graaff?
(After all the charge is gone from the metal dome the balls will stop “dancing”.)

Name:____ Date:____________

ACTIVITY 6: DANCING BALLS ACCESSORY

PROCEDURE:

1. Set up the apparatus as shown in diagram 11.
2. Move the discharge wand as far away from the collecting sphere as possible.
3. Turn on the van de Graaff for 10-15 seconds and observe what happens to the aluminum balls.

Diagram 11

OBSERVATIONS:

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QUESTIONS:

1. What is the charge on the aluminum balls before the van de Graaff is turned on? Justify your answer.

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2. Using your knowledge of conduction and induction, what do you think the charge

is on the aluminum balls soon after the van de Graaff is turned on but before the balls touch the top of the tube? Justify your answer using conduction or induction in your response.

3. What is the charge on the top of the tube after the balls hit the top of the tube? Justify your response using the term conduction or induction.

4. Explain why the metal balls come to rest in the middle of the tube in terms of charge.

PROCEDURE CONTINUED:

4. Place your finger on the metal top of the tube and leave it there.
   Record your observations:

QUESTIONS:

1. When you touch the top of the tube, what happens to the positive charge on top of the tube?

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2. What happens to the charge on the metal balls when they touch the top of the tube?

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3. What happens to the charge of the metal balls as they touch the bottom of the tube after touching the top? Explain in terms of charge, why the balls rise from the bottom again.

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4. What happens after all the charge is gone from the metal dome on the van de Graaff?

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ACTIVITY 7: OSCILLATING PITH BALL
(TEACHER ANSWERS)

PROCEDURE:

1. Set up the apparatus as shown in diagram 12. Make sure that the pith ball (little silver ball attached to the fishing wire) is outside and touching the cup.
2. Move the discharge wand as far away from the collecting sphere as possible.
3. Turn on the van de Graaff for 10-15 seconds and observe what happens to the pith ball.

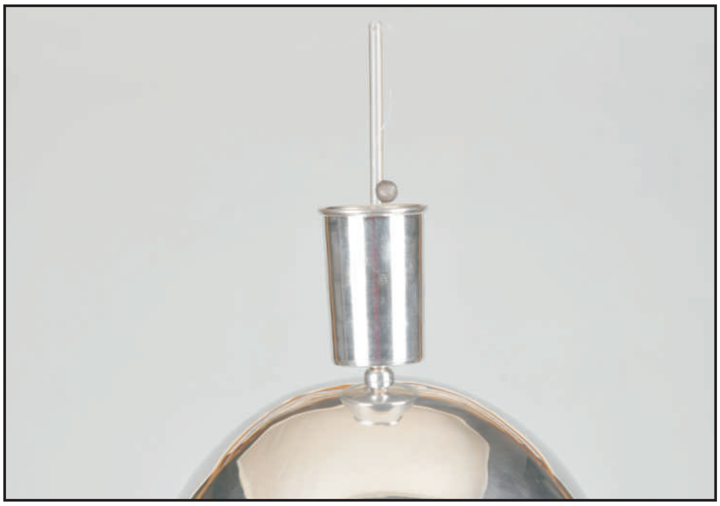

Diagram 12

OBSERVATIONS:

(The ball moves away from the cup and hovers in the air. After a few seconds the ball drops back down and as soon as it touches the outside cup it rebounds quickly and hovers again.)

QUESTIONS:

1. What is the charge on the pith ball before the van de Graaff is turned on? Justify your answer.

   (Before the van de Graaff is turned on, the pith ball is neutral because it neither attracts or repels other objects.)

2. Using your knowledge of conduction and induction, what do you think the charge is on the pith ball soon after the van de Graaff is turned on but before the ball begins to fall? Justify your answer using conduction or induction in your response.

   (The pith ball must be positively charged because it is repelled from the top of the van de Graaff and like charges repel. There is a metal path from the top of the van de Graaff to the metal cup to the metal pith ball, therefore, the pith ball is charged by conduction.)

3. After a while the ball begins to lose some of its net positive charge to the air and the force of repulsion between the cup and the pith ball decreases. What force(s) bring the pith ball back towards the cup?

(The force of gravity brings the ball back towards the cup. Also if the pith ball loses enough charge to be neutral, there is an electrostatic force between the positively charged cup and the neutral pith ball.)

4. Explain why the pith ball suddenly springs away from the cup as soon as it touches the cup. Use the word charge in your explanation.

(The pith ball acquires a positive charge by conduction as soon as it touches the positively charged cup. Since like charges repel, the pith ball is repelled from the cup.)

PROCEDURE CONTINUED:

4. Recharge the cup and then touch the pith ball with the palm of your hand as it hovers outside the cup and record your observations.

Record your observations:

(The pith ball immediately travels towards the cup and the swings back to my hand in rapid succession until eventually coming to rest)

QUESTIONS:

1. When you touch the pith ball, what happens to the charge on the pith ball?

(Your palm acts like a ground, touching the pith ball allows negative charges to enter the pith ball and become negatively charged.)

2. Touching the ball with your hand is an example of charging by conduction or induction?

(Charging by induction. The pith ball is near a positively charged object, it touches a ground therefore allowing the charges to enter the pith ball through the hand, giving the pith ball a net negative charge.)

3. After your hand touches the pith ball and it acquires a new charge, does the pith ball attract or repel the positive cup?

(The negative pith ball is attracted to the positive metal cup.)

4. What happens after all the charge is gone from the metal dome on the van de Graaff?

(After all the net positive charge has left the van de Graaff through my hand, the charge of the pith ball and cup are both neutral and the ball will come to rest against the side of the cup.)

Name:____ Date:______________

ACTIVITY 7: OSCILLATING PITH BALL

PROCEDURE:

1. Set up the apparatus as shown in diagram 12. Make sure that the pith ball (little silver ball attached to the fishing wire) is outside and touching the cup.

2. Move the discharge wand as far away from the collecting sphere as possible.

3. Turn on the van de Graaff for 10-15 seconds and observe what happens to the pith ball.

Diagram 12

OBSERVATIONS:

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QUESTIONS:

1. What is the charge on the pith ball before the van de Graaff is turned on? Justify your answer.

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2. Using your knowledge of conduction and induction, what do you think the charge is on the pith ball soon after the van de Graaff is turned on but before the ball begins to fall? Justify your answer using conduction or induction in your response.

3. After a while the ball begins to lose some of its net positive charge to the air and the force of repulsion between the cup and the pith ball decreases. What force(s) bring the pith ball back towards the cup?

4. Explain why the pith ball suddenly springs away from the cup as soon as it touches the cup. Use the word charge in your explanation.

PROCEDURE CONTINUED:

4. Recharge the cup and then touch the pith ball with the palm of your hand as it hovers outside the cup and record your observations.

   Record your observations:

QUESTIONS:

1. When you touch the pith ball, what happens to the charge on the pith ball?

2. Touching the ball with your hand is an example of charging by conduction or induction?

3. After your hand touches the pith ball and it acquires a new charge, does the pith ball attract or repel the positive cup?

4. What happens after all the charge is gone from the metal dome on the van de Graaff?

DEMONSTRATION: SPIKED ARM WHEEL

PROCEDURE:

1. Place the pointed 4mm plug into the top of the charging dome and place the star on top of the point as shown in diagram 13.
2. Move the discharge wand as far away from the charging dome as possible.
3. Turn the van de Graaff on for about 10 seconds and observe what happens.

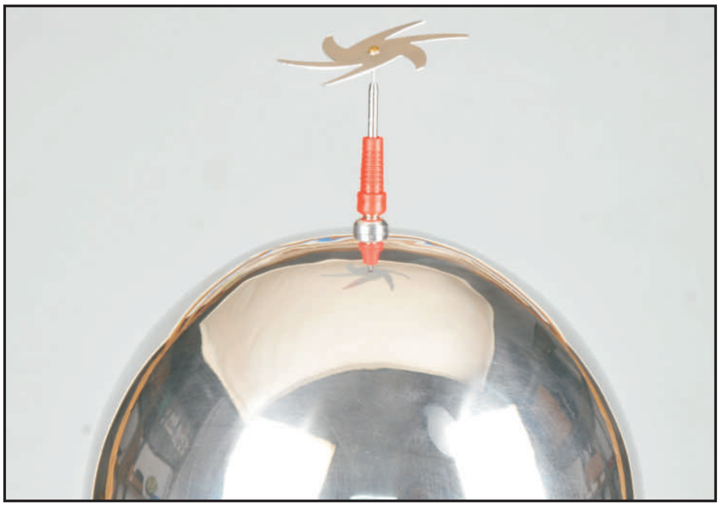

Diagram 13

This demonstration uses the idea that charge will collect on the outside of a charged surface and accumulate at a point. The pointed end of the star will have a greater charge density and therefore more charge will "leek" into the air from the point. Since charge has mass and that mass is leaving from the end of the star points, the star is propelled forward. This fits with Newton's third law. For every action, there is an equal and opposite reaction. The charge leaves from the tips of the stars moving tangent and clockwise and the star therefore is pushed counterclockwise around in a circle.

4. To prove that the star only rotates one way, move the star in a circle clockwise and move the discharge arm so it is touching the collecting dome.
5. Turn the van de Graaff on and then observe the star, it will continue to rotate clockwise.
6. Now move the discharge arm away from the collecting dome so that charge begins to form on the dome.
7. Watch as the star slows down and then begins to rotate the other way.

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