



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.

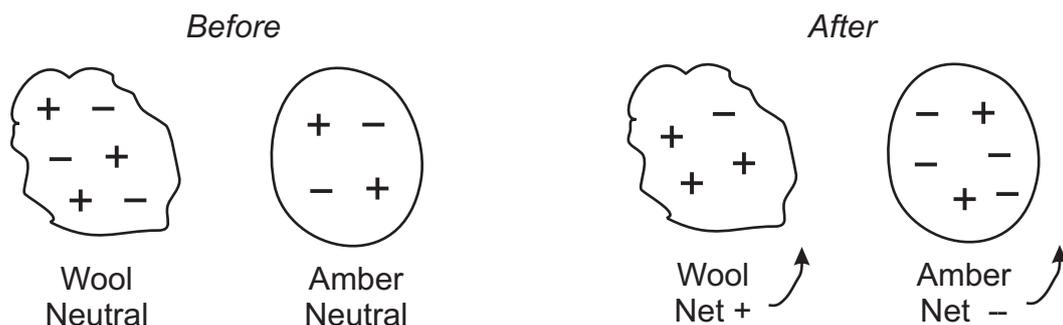


Diagram 1

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.

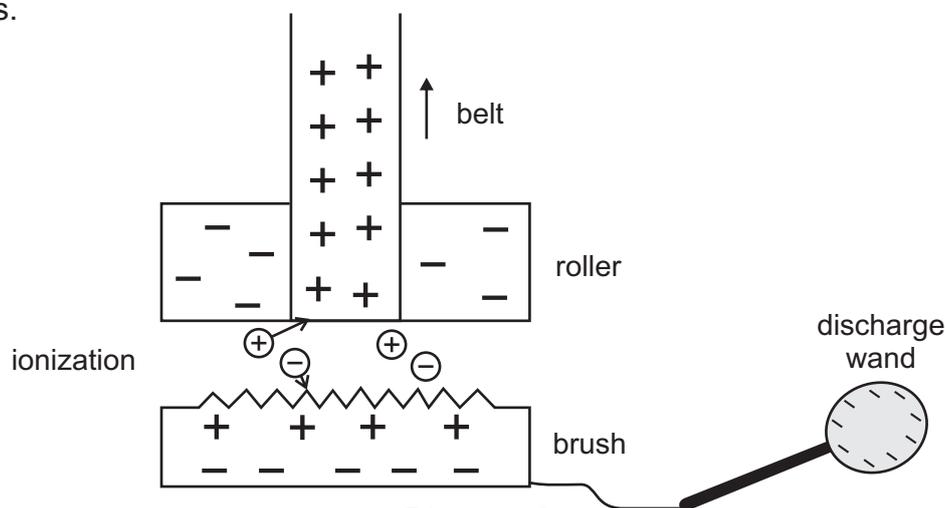
Ionization

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 transferred 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.



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.

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

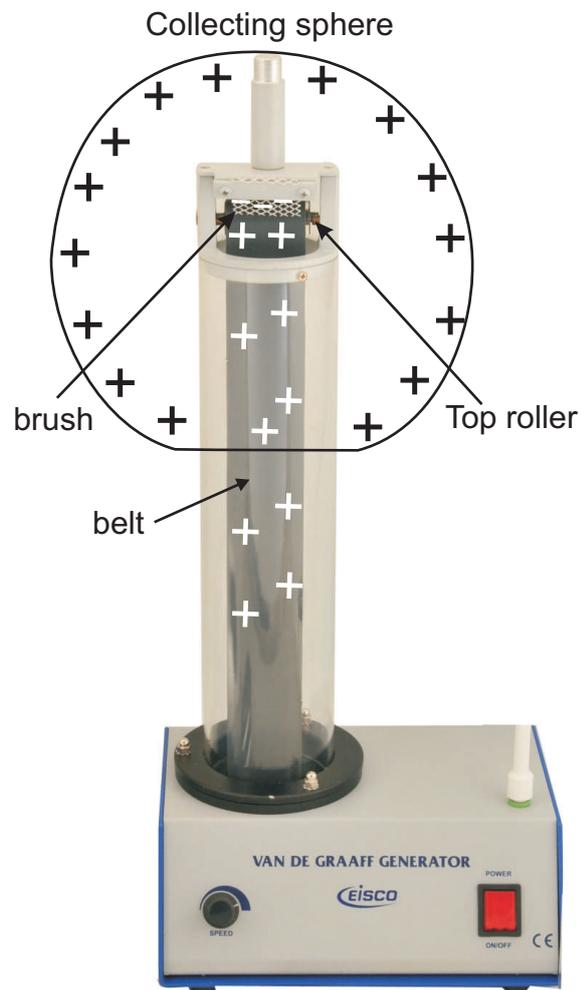


Diagram 3

surrounding the top of the device. The conductor will discharge 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)

<i>Name of Part</i>	<i>Quantity</i>
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)

<i>Name of Part</i>	<i>Quantity</i>
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:

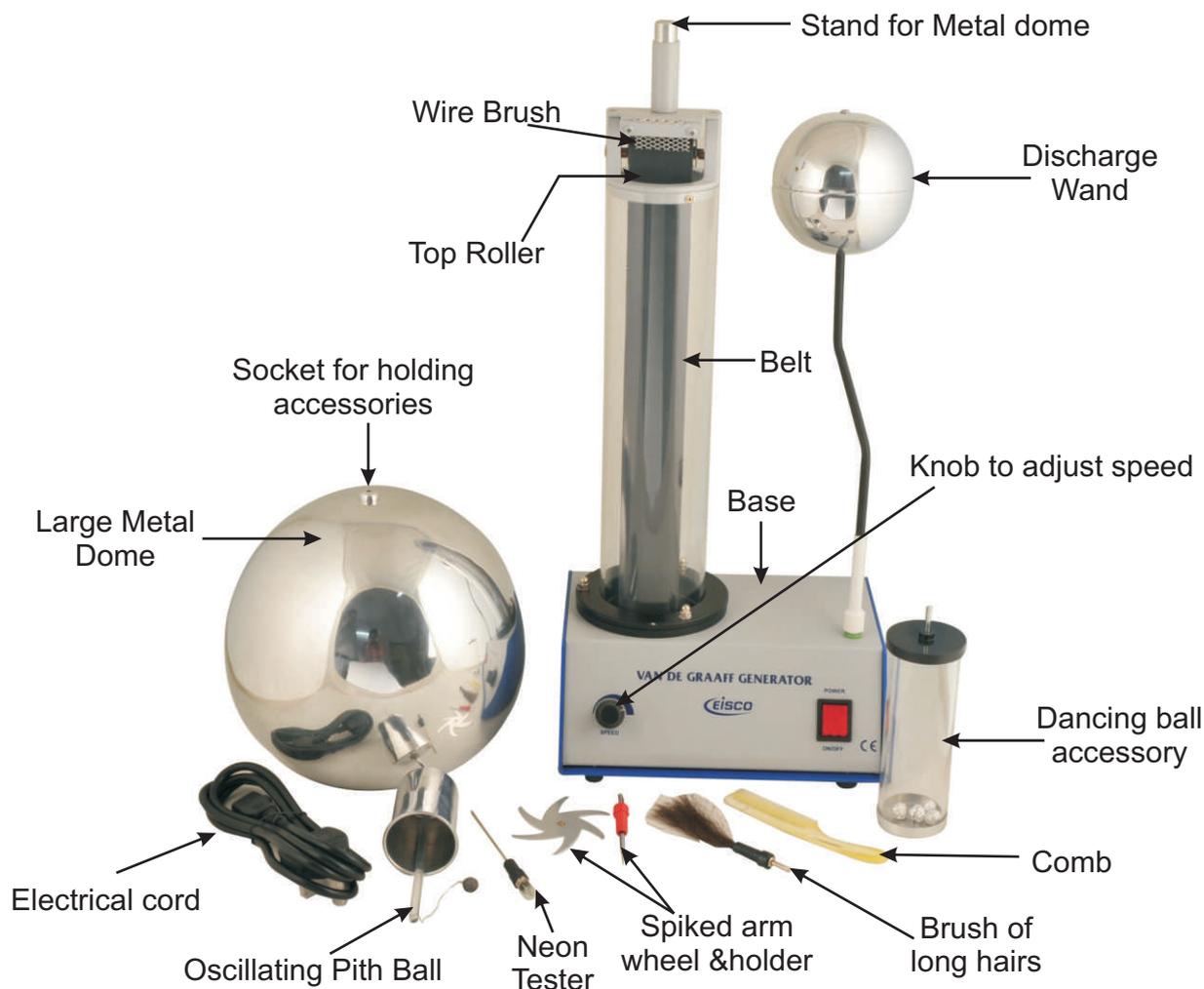
Warning: Persons with cardiac pacemakers should never operate the van de Graaff generator.

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.

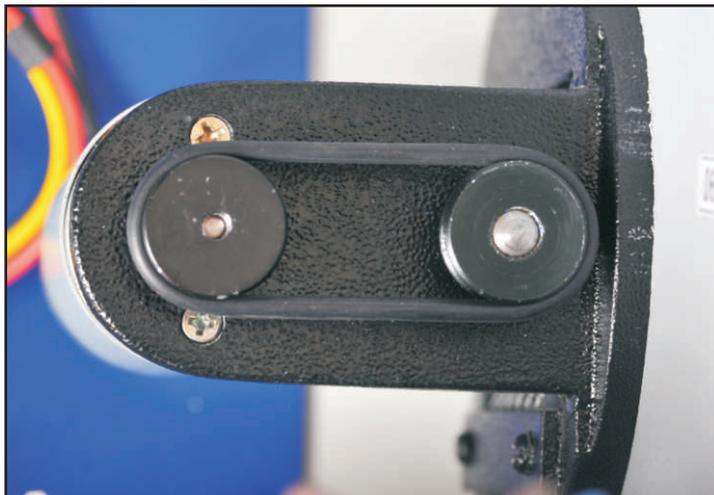


Diagram 5

Cleaning: