Teaching guide

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MANUAL & MOTORIZED VAN DE GRAAFF GENERATOR

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LIST OF MATERIAL INCLUDED: DESCRIPTION

1 Power supply 220V/12V
1 Van de Graaff machine
1 Pulley and fitting belt for hand operation
1 Mobile discharge sphere
1 Ground wire
1 Electric plume
1 Electric whirl

DESCRIPTION OF MATERIAL

SOME CONCEPTS OF ELECTROSTATICS

Electrostatic generators are machines in which mechanical work is transformed in electrostatic energy. The functioning of these kind of generators, such as the Van der Graaf one, is based on some simple electrostatic phenomena, illustrated below.

1 ° THE TRIBOELECTRICITY

Since the days of ancient Greece it was known that, rubbed with wool, amber acquires the property of attracting small light bodies, such as small pieces of cork, paper, hair, etc. The terms that describe this phenomenon, in fact, has a Greek origin: tribos means rubbing and electrton means amber.
Many centuries later it was discovered that there are two different kinds of electricity, one positive and one negative. So it was possible to compile a table which lists several substances in a particular sequence, defined triboelectric serie, which has this property: rubbing a substance A with a substance B, which in the triboelectric series comes after A, the first becomes electrified positively and the second negatively. The polarities are reversed in the opposite case. The knowledge gained in the twentieth century on the electrical nature of the matter has allowed us to understand that electrostatic charging of two different bodies does not necessarily require the rubbing. The electrification also manifests itself with the simple contact.
Precisely, when you put in contact two different bodies, in some points of their surfaces, the distances between different atoms become so small, that it may happen that some electrons pass from one body to another, if the binding energy of the electrons in the second body is larger than the binding energy in the first. Consequently, the body that acquires electrons becomes negatively charged, the other becomes positively charged (Fig. 1). If the materials in contact are conductors, in a fairly short time, defined relaxation time, the electric charges will be distributed uniformly. If the materials are insulators, electrical charges remain localized. In conclusion, the rubbing between the surfaces increases the number of contact points, thus favoring the electrostatic charging, but it is not the cause.

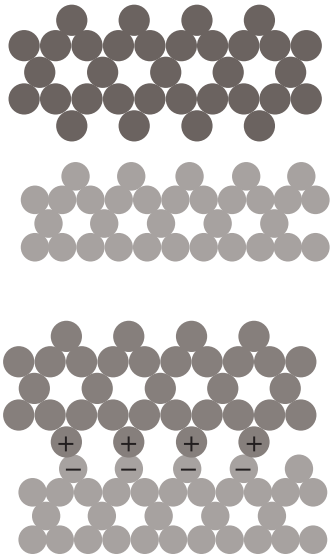

Fig. 1

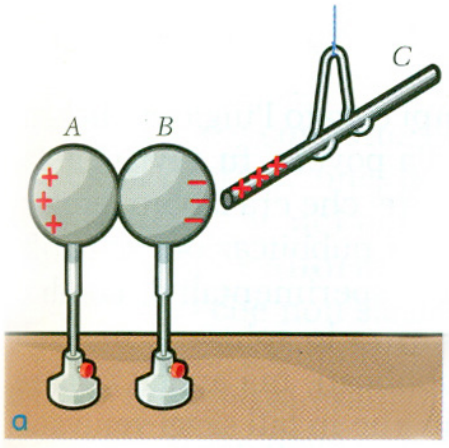

Fig. 2

2 ° ELECTROSTATIC INDUCTION

Each time that a metallic conductor (induced), isolated and the neutral state, is brought near an electrified body (inductor), without touching it, the conductor becomes also electrified, by induction.
For example, let's assume that the inductor is electrified positively, the induced is negatively charged in the nearest part, and positively on the far side (Fig.2). Under the action of the positive charge of the inductor, in fact, many free electrons of the inducted is attracted by the positive charges of the inductor, leaving an equal number of gaps in the most distant part.
This is a situation of electrical balance. In fact, if the inducer is removed, the induced returns to its original neutral state.

3° TIP-SHARP EFFECT

In the conductors of the excess electric charges, they are localized on the surface, by electrostatic repulsion. Their distribution, however, depends on the shape of the conductor. In a spherical conductor, for example, the distribution of charges is uniform. If Q is the electric charge present on the surface and A is the surface area, is defined *charge density* (σ) the ratio between the charge and the area; that is

$$\sigma = \frac{Q}{A}$$

So, in a spherical conductor the charge density is constant in every point of its surface. (Fig. 3).

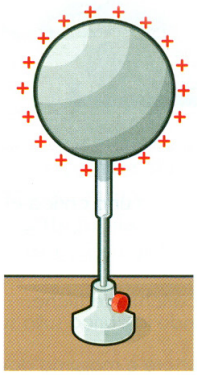

Fig. 3

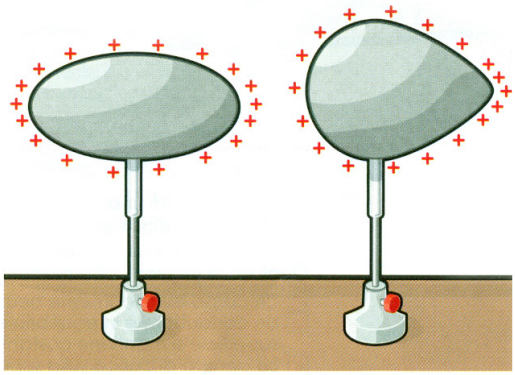

Fig. 4

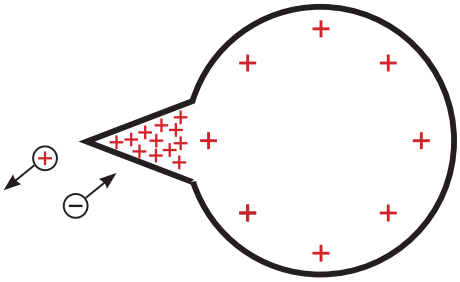

Fig. 5

However, in conductors that have not spherical shape the charge density is not uniform, since the electric charges are concentrated where the radius of curvature of the surface is smaller, despite the strong electrostatic repulsion (Fig. 4).
This phenomenon is enhanced if the conductor is provided with tips. Here the concentration of the charges is so high that produces a large charge density.
And is possible to show that, near an electrified conductor, the intensity of the electric field is proportional to the charge density. Consequently, near the tips, the electric field is so intense that causes ionization of the gas molecules that form the air; some atoms, near the tips, lose electrons, causing the creation of ions.
If a tip is positively electrified, for example, negative ions of the air are attracted, while the positive ions are repelled. (Fig.5).

PRINCIPLE OF OPERATION

This type of electrostatic generator is a simplified teaching model of the one invented in 1929 by the American physicist Robert Van De Graaff. The essential parts of this machine are,

a ribbon of insulating and elastic material;
a teflon roller;
a nylon roller;
a spherical collector;
two metal combs
an electric motor.

The generator scheme is shown in Figure 6.

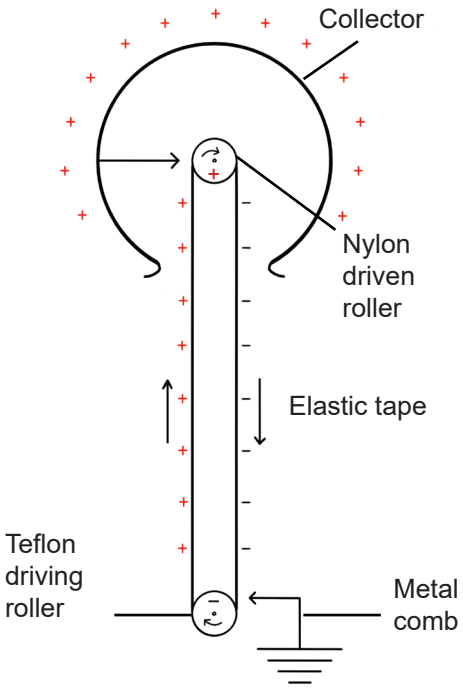

Fig. 6

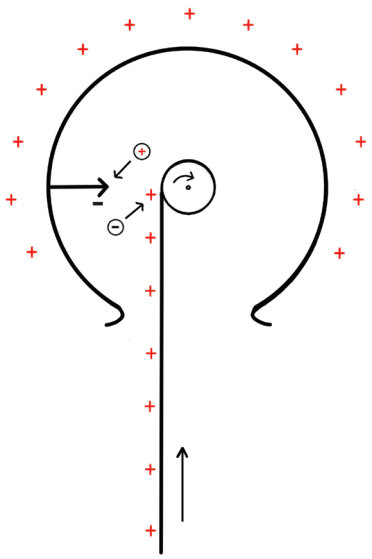

Fig. 7

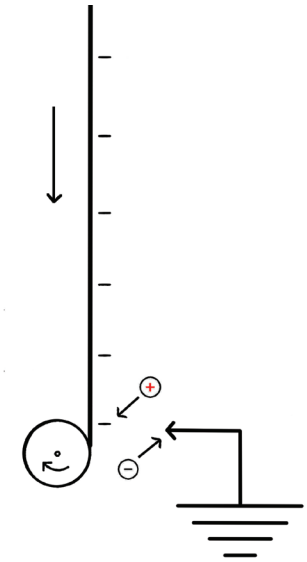

Fig. 8

When the electric motor is put into operation, the elastic tape, under slight tension, becomes electrified positively, while the driving roller made of Teflon, is negatively electrified, since in the triboelectric series the material of which the tape is made comes before the teflon. The tape carries the positive charges within the collector, which is provided with a metal comb, whose tips are very close to the tape. By induction, the comb tips are negatively charged, while the collector is positively charged. (Fig. 6). Thus, the air between the tape and the comb is the seat of an intense electric field, which ionizes the air of the gas atoms. The positive ions are attracted to the comb, neutralizing its negative charge, while negative ions are captured by the tape, making it neutral. (Fig. 7).

But the tape, once discharged, is in contact with the driven roller, which is made of nylon. Since in the triboelectric series the material of which the tape is made comes after nylon, the driven roller is positively charged, while the tape is negatively charged. Before arriving at the driving roller, the portion of the tape, negatively charged, passes in close proximity to a metal comb, which is connected to ground. So the negative charges carried by the going down tape, are discharged to the ground, and the tape returns to neutral, to perform a second cycle. (Fig. 8).

In the original Van de Graaff machine an additional power supply was used to charge the lower tip. In the machines used in schools, charges are produced by contact between the belt and rollers. They are called self-excited machines.

This Van de Graaff generator is able to generate a potential difference that, in a dry environment, can reach 100.000 V, producing a spark by several millimeters. As the current used for the machine is low (few µA), there is no electric hazard for users, but please read carefully the following warning.

WARNING:

1. **FOR YOUR SAFETY ALWAYS WEAR PROTECTION GOGGLES WHEN USING THE MACHINE.**
2. **NEVER CONNECT THE MACHINE TO ADDITIONAL CAPACITORS.**
3. **PEOPLE SUFFERING FROM HEART PROBLEMS OR PACEMAKER CARRIER SHOULD NEVER COME CLOSE TO AND USE THE VAN DE GRAAFF GENERATOR.**
4. **CONNECT GROUND WIRE BEFORE USE.**
5. **DO NOT USE ELECTRONIC DEVICE CLOSENESS OF THE APPARATUS IF IT IS IN FUNCTION: The generator of Van de Graaff could damage them.**

INSTRUCTIONS FOR THE ELECTRIC OPERATION

- The generator is supplied ready for use.
- Connect one end of the ground wire into the jack on the base of the generator and the other end of the cable to a grounding system (fig. 9). This is necessary for your safety and for proper operation.

Fig. 9

- Check for the belt that connects the generator to the engine and connect the power supply to the motor (Figure 10).
- Activate the motor and check the distance at which the arc keeps sparkling.

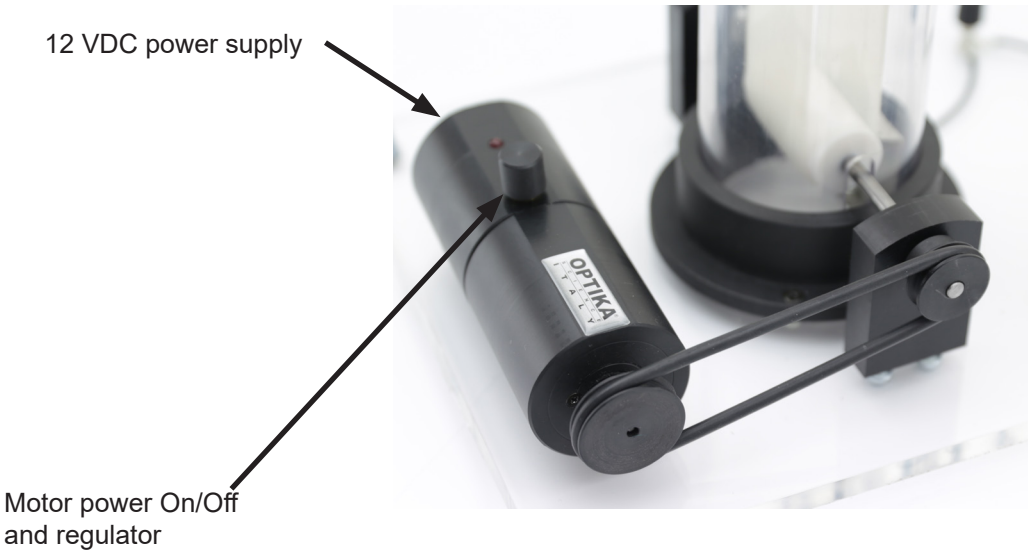

Fig. 10

HAND OPERATION

- Disconnect the motor and remove the short belt. Connect the bigger belt to the pulley for manual use (fig. 11).

Fig. 11

FEASIBLE EXPERIENCES WITH SUPPLIED EQUIPMENT

1) The electric feather

Arrange the electric feather on the generator as shown in figure 12. The tufts, charging themselves with charges of the same sign, repulse themselves.

2) The electric whirl

This accessory allows you to check the power of the points. It consists of three bent tips. If you fix the whirl on the generator and turn it on, the whirl begins to turn (Fig. 13). This is because the charges are placed on the whirl ends, creating an intense electric field, and, as in the air there are both negative and positive charges, the whirl tips attract the opposite charges, while the charges are the same sign rejected, creating a repulsive force that spins the whirl.

Fig. 12

Fig. 13

By purchasing the Van der Graaff generator accessory kit cod. 5404, you can also do the following experiences.

3) The electrostatic engine

1. Install the electrostatic engine on universal support.
2. Connect the engine with two cables to the generator.
3. Turn the motor on.
3. Using an insulator rod, gently push the ball.

An insulating material ball, is placed between two metal disks, so that it can roll on the lower disk without touching the upper disk. Both discs are provided with a perforated cylinder that allows the connection with the electrical machine, as is shown in figure 14. To understand, imagine that the lower disk is positively polarized and the upper disk, negatively. From the edge of the upper disk, a stream of electrons accumulates on top of the sphere. Because of the symmetry in their distribution, the resultant of the forces acting on the center of gravity of the sphere is zero. Giving a small boost to the ball with an insulator rod, you create an asymmetry in the distribution of the charges, which rolls the ball. (Fig. 15).

Fig. 14

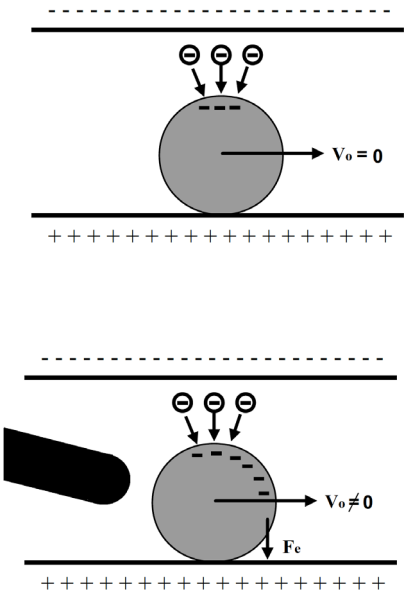

Fig. 15

4) Faraday effect

1. Install the cage on the universal support.
2. Connect the cage with a wire to the genera-
3. Turn on the generator.

As shown in the drawing and as shown in the photo, the balls that are in contact with the external surface of the metal cylinder diver-
while the
inside balls remain still, demonstrating that the charge density is distribuited on the external surface of the conductors.

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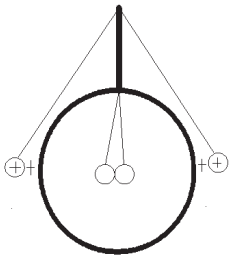

Fig. 16 Fig. 17

5) Dance of the balls

1. Install the container on the universal support.
2. Connect the container to the generator with two cables.
3. Turn on the generator

To the generator

Fig 18

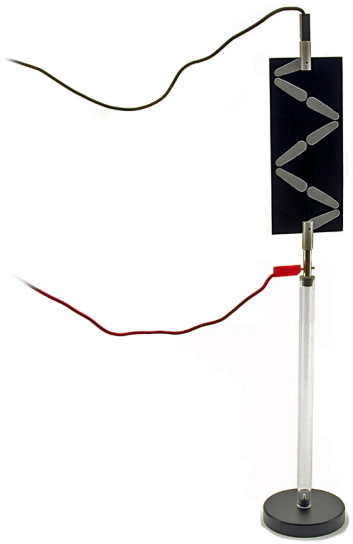

Fig. 19

The balls, covered with tinfoil, are initially at the bottom of the metal container. When you turn on the generator, the balls load itself with charges of the same sign and reject each other. The inner wall of the metal container is opposite charge and attracts the balls upwards. Then the latter fall by gravity to the bottom and so on (Fig. 18).

6) The sparkling panel

After attaching the accessory to the universal support, turn on the generator. Because the high tension, you can see little spark between the metallic areas of the panel (Fig. 19).

7) The electric pendulum

Fig. 20

1. Wrap the wire of the two spheres on the frame of the pendulum and fix it on universal support.
2. Connect the pendulum with a cable to the generator.
3. Turn on the generator.

Between the two small spheres there is a repulsive force exerted by charges with the same sign (Fig. 20).

Fig. 21

8) The electrostatic blower

1. Fixed the frame of the L-shaped electrostatic blower on the universal support.
2. Connect the frame with a cable to the generator.
3. Turn on the generator and bring a candle closer to the tip of electrostatic blower.

This experiment shows how the action of the charges launched away from a metal point can turn off the flame of a candle (Fig. 21).

9) LED with support

Bring the led with the support near the sphere of the generator and verify when the LED lights turn on (Fig. 22).

Fig. 22

Fig. 23

10) The articulated discharger

Use these tools to discharge the remaining charge of the Van de Graaff generator after each experience.

NOTICE

Any difference between the features of the parts included in the kit and those of the above pictures is due to technological updating.