UNIT 9: ELECTRICITY

Content:

Unit 9 Electricity

9.1. The electric charge
9.2. Types of electrification
9.3. Conductors and non-conductors
9.4. Electroscope
9.5. Electrophorus
9.6. The van der Graaff generator

Annex: History of electricity

Learning Aims:

At the end of the unit, the student will know:

- The different kinds of electricity and how are produced.
- The differences between conductors and non-conductors of electricity.
- How to describe some devices used in electrostatics.
- How an electroscope works.
- How an electrophorus works.
- How the van der Graaf generator works
- To use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

1.  Choose the right answer:

1.1. Substance in witch charges move easily are called:

a) Insulators
b) Conductors

1.2. Negative charges _____ each other.

a) Attract
b) Repel

1.3. A positive charge and a negative charge _____ each other.

a) Attract
b) Repel

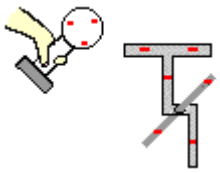
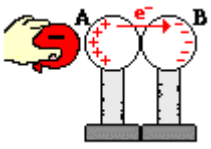
1.4. A particle with excess of electrons is

a) Negatively charged
b) Positively charged
c) Neutral

2. Which particle of an atom is responsible for electric conduction?

3. If we approach two balloons, after rubbing then with our hair, they repel each other, why?

Key words:

Electric charge + −	**Negative** or **positive** charge in particles is due to an excess or deficiency in **electrons**.
Friction electrification 	**Friction electrification** occurs when two surfaces are rubbed together
Conduction electrification 	Electrification by **contact** between a charged object and a neutral object. Charges of the charged object distribute between the two objects
Induction electrification 	An insulating conductor object is charged by another charged object **without contact** between the two objects

Conductor 	Material where **electrons** or **ions** have freedom to **move** around
Insulator 	In insulators **electrons** or **charged particles do not** have freedom to **move** around
Electroscope 	Instrument for **detecting** the presence of **static electricity**.
Electrophorus 	Insulated rod and a metal plate, used to **store up** static electricity by induction.
Van der Graaff generator 	Electrostatic machine which uses a moving belt to accumulate **very high voltages** on a hollow metal globe

9.1. The electric charge

In unit 1 we talked about the composition of matter, we already know that the tiniest particle of an element is the atom, but an atom has protons, neutrons and electrons. A **proton** has **positive charge** and an **electron** has the same, but **negative**, charge of a proton. Now we can say that a substance has charge when the number of electrons and protons is different.

When atoms **lose electrons** they become **positively charged**, but when the atoms **gain electrons**, their charge is **negative**. If the number of electrons is equal to the number of protons, substances are neutral.

Like charges **repel** each other but opposite charges **attract** one another.

We talk about **static electricity** when the net electric charge is non-zero and motionless, but when charge is flowing in a particular direction, the phenomenon is known as electric current.

Questions

1. Which of the following statements are true? If the statement is false, write the correct one.

a) A neutral object becomes positively charged when electrons are removed.

b) Like charges attract each other.

c) Protons and electrons repel each other.

d) In a neutral atom the number of protons is equal to the number of neutrons.

e) A negatively charged object must have an excess of protons.

2.- What is the difference between a positively charged object and a negatively charged object?

3.- What is the characteristics of charges to be attracted?

9.2. Types of electrification

We define electrification as the process by which matter lose or gain electric charges. There are three main **types of electrification**: **Friction**, **Conduction**, and **Induction**.

1. **Friction:** The frictional charging process results in a transfer of electrons between two insulating objects which are rubbed together. In this process, an object take electrons (it becomes negatively charged) from the other object (it becomes positively charged).

Example:

When a rubber balloon is rubbed with animal fur or hair, the rubber balloon gains electrons and the animal fur loses electrons. A transfer of electrons takes place. When you rub the balloon, it becomes negatively charged, it has taken some of the electrons from the animal fur and left the fur positively charged.

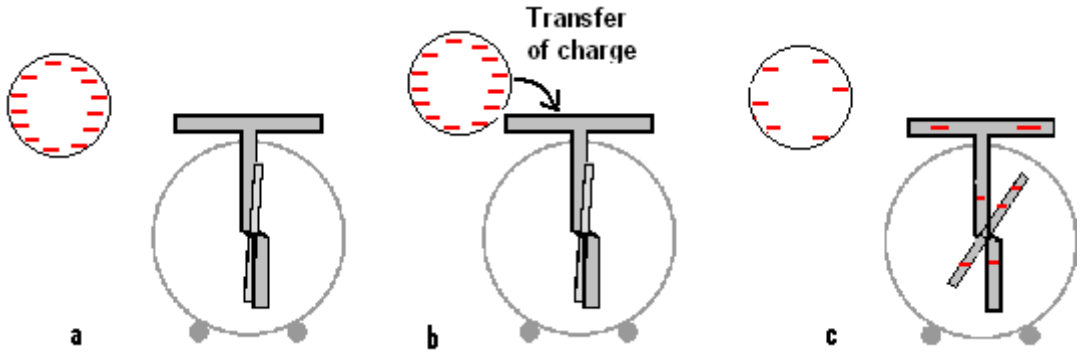
Different materials have different affinities for electrons and they can be ordered according to their affinity for electrons. In the following series, materials are ordered by their capacity to gain electrons. Materials shown highest on the table tend to have a greater affinity for electrons (gain electrons) than those below it:

Celluloid
Sulphur
Rubber
Amber
Wood
Cotton
Silk
Cat fur
Wool
Glass
Rabbit fur

2. **Conduction:** This process involves the contact between a charged object and a neutral object. Because charging by conduction involves contact, it is often called **charging by contact**. In this case, charges of the charged object distribute between the two objects.

Example:

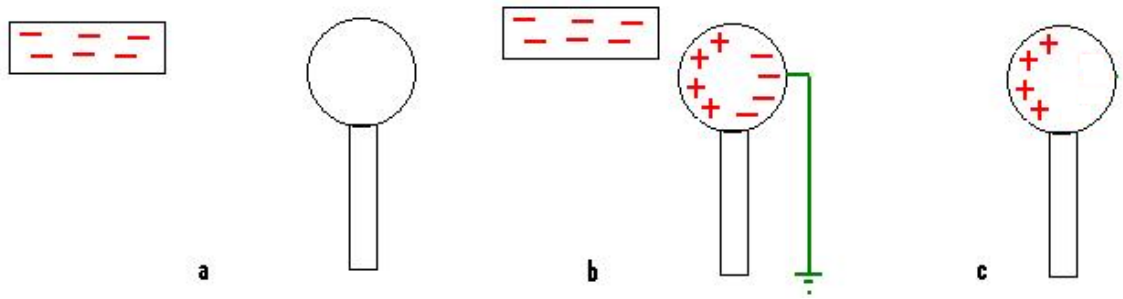
Initially we have a charged metal object and an uncharged metal on an insulating support stand (let's think of an electroscope) (**a**). If we touch the electroscope with the charged object (**b**), some of the charge will transfer over to the uncharged metal object and charge distributes the charged object and the uncharged metal (**c**).



http://www.ddart.net/science/physics/physics_tutorial/mmedia/estatics/esn.gif:
Simulation about the distribution of charges by conduction.

Induction: In this method an insulating conductor object is charged by a charged object without contact between the two objects (only approaching it) (**a**). If we approach the charged object to the insulating conductor object, a separation of charges in the insulating conductor occurs (**b**). A ground wire is used to transport negative charges (in this figure from the objet to ground) (**c**).

Note: When the object we approach is positively charged, electrons would come up the grounding wire to be closer to the object. Observe that that when an object is charged by induction, their charge is opposite to the charged object.



In webpage http://www.glenbrook.k12.il.us/GBSSCI/PHYS/CLASS/estatics/u8l2c.html you will find a curious way of charging by induction.

Questions

1.- Tell if the following statements are true or false. Change the false statements for the correct ones:

a) When a neutral object is charged by friction, there is a transfer of protons between the two insulating objects.

b) If we want to charge an object negatively with only the help of a positively charged object, the induction method is the more appropriate to do it.

c) A negatively charged balloon sticks to the wall because there is a distribution of charges in the wall and negative charges of balloon attract the positive charges of wall.

d) If we use a negatively charged plastic rod to charge a metal plate by induction, the charge on the metal plate will be positive.

e) In the process of charging an object by friction, charged acquired by the two objects have the same magnitude but the sign is different.

2.- What is the name of the process of charging a neutral body by touching it with a charged body?

3.- If you comb your hair and the comb becomes negatively charged, how is the charge of the hair?

4.- What is the difference between charging an object by conduction and charging by induction?.

5.- If glass is rubbed against silk, which would end up with a negative charge? Why?

6.- Why a rubber rod becomes negatively charged when rubbed with fur?

7.-.
a) Two neutral metallic cans are touching each other. A negatively plastic rod is approached (without touching) to one of the cans, once the cans are charged, they are separated. Explain what happen to both cans.

b) The previous process is repeated but this time, approaching a positively glass rod. Explain what happen in this case.

8.- Explain the process to charge positively an insulating metallic sphere.

9.-
a) What happen with charges of a negatively charged rod when touching an insulated neutral metal?

b) What happen if rod in question (**a**) is positively charged?

9.3. Conductors and non-conductors

Materials can be divided in **conductors** or **non-conductors** (insulators) of electricity.

Conductors: In **conductors**, electrons or ions have freedom to move around.

Example:

Metals are good conductors of electricity because the outermost electrons in the atoms are loosely bound to the nucleus.

When salts are dissolved in water their ions (cations and anions) can move freely through the solution.

Non-conductors (insulators): When electrons o charged particles do not have freedom to move around the material, we are talking about **non conductors** or **insulators**.

Example:

Glass, cotton, plastic are examples of insulators (resistant to electron motion).

Questions

1.- What is the difference between a conductor and an insulator?

2.- Explain why solid salts do not conduct electricity but they do in aqueous solution.

3.- Why metals are good conductors of electricity?

9.4. Electroscope

An **electroscope** is an instrument for detecting the presence of static electricity. The basic electroscope consists of two thin metal leaves suspended from a metal hook. When a charged object is approached to the hook, metal leaves acquire the same charge as the object. As the two leaves have the same charge, they repel each other.

Electroscopes are used to know if and object is charged (**a**) or to find the sign of a charged object (**b**).

a) We know if an object is charged when the electroscope's leaves separate when the object touches the hook of the uncharged electroscope.

b) To know the sign of a charged object, we need to approach the object to a charged electroscope; if the deflection decreases the charge of the object has opposite sign than the electroscope charge, but if the deflection increases, then the charge is the same as the electroscope.

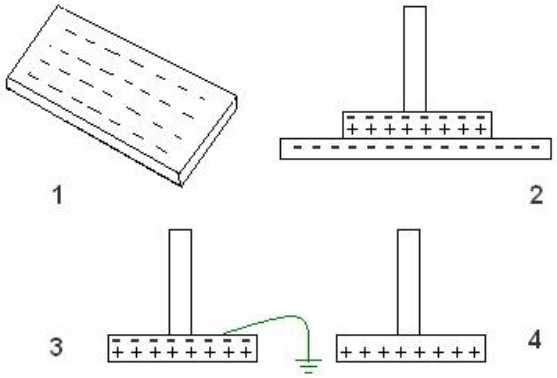
http://www.kalipedia.com/fotos/electroscopio.html?x=20070924klpcnafyq_355.les

9.5. Electrophorus

An **electrophorus** is a simple, high-voltage electrostatic generator. It consists of a metallic disc and an insulated handle. This apparatus is charged by **induction**. Steps to charge an electrophorus:

1. With an animal fur rub a plastic surface (this surface becomes negatively charged).
2. Place the metallic disc of electrophorus onto the negatively charged plastic. Charges in metal will be distributed, the positive charges will be attracted by the negative charges of plastic and the electrons in the metal will occupy the opposite place.
3. Remove the electrophorus from the plastic surface, then eliminate the negative charge with a ground wire or touching the metal disc briefly (the negative charges will flows to earth through the wire or your body)

4. The electrophorus will be charged positively.



You can use an electrophorus to:

- Produce small sparks.
- Deflect the leaves of an electroscope
- Blink a small neon bulb.
- See the initial attraction of soap bubbles and their final repulsion (once they become charged, they float away due to repulsion off the same sign charges).
- Pick up small pieces of paper, lint, etc.

9.6. The van der Graaff generator

The **Van der Graaff generator** is also a static electricity machine that can generate very high voltages.

It consists of a large hollow metallic sphere supported by an insulating column. Electric charges of the same type (either positive or negative) are put onto a moving belt, carried upwards by the belt and put into the hollow sphere by sharply pointed combs, and left there. This is a continuous process, the belt collects charge at the bottom and this charge is stored at the top sphere. As the amount of charge on the dome increase, its voltage also increases.

Potential differences in Van de Graaff generators can be of 5 megavolts. The larger radius of the sphere is, the higher the potential.

One of the largest Van de Graaff generators, built by R. J. Van der Graaff, is found at Boston's Museum of Science. It has two joined spheres of 4,5 m each and. This generator can reach a voltage of 2 megavolts.

The **voltage** is very high, but the current is tiny, therefore it is quite safe to use this generator.

In cold and dry days, the Van der Graaff generator works better because discharge is more difficult.

There are many web sites with experiments related to Van der Graaff generator. In the following web sites you will find videos simulations:

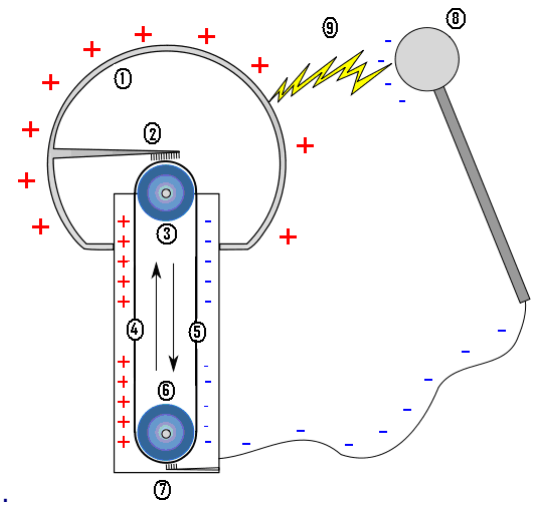
1.- http://www.youtube.com/watch?v=AhLbYaloxsE&hl=es: a good video, explaining how the generator works, production of sparks and why an electric whirl spins rapidly in a direction that is away from the points.

2.- http://www.youtube.com/watch?v=xhvc-z0anB0: This video contains different experiments: spinning of an electric whirl, movement of Styrofoam balls inside a glass jar, pulling apart sheets of paper.

3.- **http://www.physics.ucla.edu/demoweb/demomanual/electricity_and_magnetism/electrostatics/van_der_graaff_experiments.html**: This is a very interesting web site with explanations and simulations using different accessories: electric whirl, electroscope, smoke precipitator (when smoke is blown into a tube (for example, from a cigarette) rapidly disappears when the electrodes on the ends of the tube are connected to the generator), Styrofoam balls, etc.

4.- **http://teleformacion.edu.aytolacoruna.es/FISICA/document/fisicaInteractiva/sacaleE_M2/Triboelecetricidad/vanderGraff/GeneradorEVG_Trabajo.htm:** In this Spanish webpage there is a good explanation of van der Graaf generator.

5.- http://en.wikipedia.org/wiki/Van_de_Graaff_generator: Explanation and history of Van der Graaff generator. This web page also includes a picture of the components of Van der Graaff generator:



1. Hollow metallic sphere.
2. Electrode connected to the sphere, a brush ensures contact between the electrode and the belt.
3. Upper roller.
4. Side of the belt with positive charges
5. Opposite side of the belt with negative charges
6. Lower roller
7. Lower electrode (ground)
8. Spherical device, used to discharge the main sphere
9. Spark produced by the difference of potentials

Questions

1. Which of the following statements are true? Change the false statements for the correct ones.

a) A neutral electroscope is charged by touching it with a positively charged glass rod. The leaves of electroscope acquires a positive charge

b) An electroscope, positively charged, is touched by a negatively charged balloon. The leaves of electroscope separate more.

c) We discharge a negatively charged electroscope touching it because electrons go to ground through our body.

d) We discharge a positively charged electroscope touching it because protons go to ground through our body.

e) The leaves of a charged electroscope will deflect even more when we touch it with a charged rod, independently of the sign of charges.

2.- Explain the process to charge an electrophorus.

3.- A balloon is rubbed with an animal fur. Then, we touch a negatively charged electroscope with the balloon. What is the charge of the balloon? Why?

4.- After watching the videos or simulations on the previous web pages related to the Van der Graaff generator, answer these questions:

- **a)** Why sparks are produced between the two spheres?
- **b)** Why the electric whirl spins in a direction that is away from the points?
- **c)** Why Styrofoam balls jump inside the glass jar?
- **d)** Why the sheets of paper are pulling apart?
- **e)** What happen if the sphere is touched with an electroscope?
- **f)** Why does the smoke disappear inside the tube?
- **g)** What happen to hair when an insulated person touches the sphere? Why?

Annex: History of electricity

It was known by the Greek philosopher **Thales of Miletus** (640-546 B.C.) that when amber was rubbed acquired the property of attracting light objects. The word electricity comes from ***electron***, Greek word for amber. The first static Electric generator was invented in 1675 by **Otto von Guericke**, but except for some medicinal applications, electricity had little use.

Later, in 1729 **Stephen Gray** tested that electricity can move through conducting wires and that charges of electrified objects are located on their surfaces.

Discovery that there are two kinds of charges, negative (**resinous**) and positive (**vitreous**) was made by **Charles Francois du Fay** in 1733.

In 1745, **Pieter van Musschenbroek**, from Leiden, Netherlands, invented the **Leyden jar**. The Leyden jar[1] is a device that stores static electricity between two electrodes on the inside and outside of a jar.

It was in 1752 when **Benjamin Franklin** proved that lightning (flow of electrons between the ground and the clouds) had an electrical nature. He flew a silken kite with a metallic skeleton, holding the end of the kite silken string with an iron key, during a thunderstorm. When lightening occurred, a spark was produced from the key to his wrist. With this experiment B. Franklin proved that lightning had electrical nature.

Throughout the next years, there were many experiments related to electricity, but we have to point out the invention of the incandescent filament bulb in 1878 by the British scientist, **Joseph Swan**, and, a year later by the American **Thomas Edison**. This is one of the first practical uses of electricity.

Among other inventions related to the uses of electricity we have to stand out:

- In1786, **Luigi Galvani** found that legs of a dead frog moved quickly when they were touched by a metal knife. Galvani thought that legs of frogs contained electricity.

- In 1792, **Alessandro Volta** tested that movement of leg's frog was due to the movement of charges between the two metals (the steel knife and the tin plate where the frog was lying) separated by a moisture material. Volta invented the first **electric battery**, in 1800, it was made from alternating discs of zinc and copper with pieces of cardboard soaked in brine between the metal discs.

- In 1831, **Michael Faraday** discovered how to produced electricity moving a magnet inside a coil of copper wire, (**electromagnetic generator**).

- The first motor that allows generating **alternating current** was inventing in 1882 by **Nikola Tesla**. AC, rather than DC, enables the transmission of large quantity of electrical power using higher voltages via transformers

Westinghouse Electric, founded in 1886 by **George Westinghouse**, was the first company that constructs the **hydroelectric power station** at Niagara Falls to transmit electricity to long distances.

The first power plants used **water** power or **coal** as sources of energy to make electricity commercially. In the 1950's **gas**, **oil** and **nuclear power** were introduced.

[1] Your teacher will show you a video explaining the construction of a Leyden jar, how to charge it with a screen TV and how to discharge the Leyden jar (a spark is produced).

Project:

The following projects are thinking to work individually or in groups of two. Choose one of them, or any other related to electrostatics:

1. Build a Leyden jar: Consult the web pages:

http://video.google.com/videoplay?docid=-7547972370900128124

http://www.alaska.net/~natnkell/leyden.htm

http://home.earthlink.net/~lenyr/stat-gen.htm

2. Build an Electroscope: Consult the webpage:

http://www.charlesedisonfund.org/Experiments/HTMLexperiments/Chapter9/9-Expt3/p1.html

3. Build a Van der Graaf generator: Consult the webpage:

http://scitoys.com/scitoys/scitoys/electro/electro6.html

Experiments:

Experiment 1: Conductors and insulators

OBJECTIVE

Test the electrical conductivity of different materials.

EQUIPMENT

Battery	Light bulb
Three Cables	Multimeter

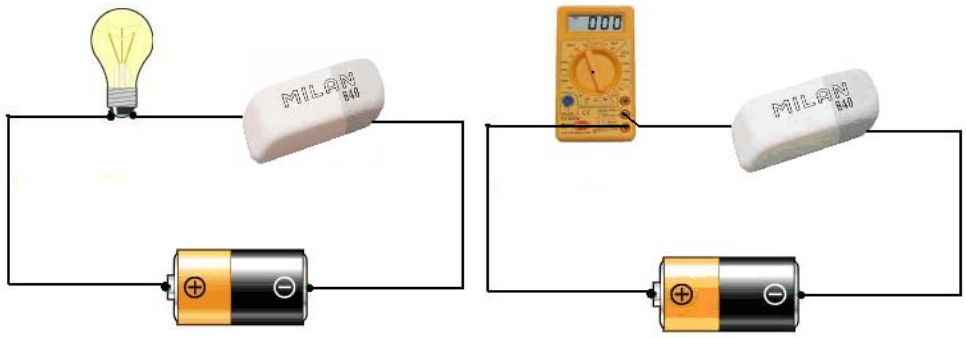
MATERIALS

Paper clips	Aluminium foil
Sulphur	Running water
Distilled water	Rubber
Plastic	Copper
Etc.	

PROCEDURE

The figure shows the circuit you have to do:

1. Use two cables to connect either terminals of the battery. A cable has to connect the battery to the light bulb and the terminal of the other one has to be free to be connected to the different materials.
2. A terminal of the third cable has to be attached to the other pole of the bulk and leave the other terminal free for the different materials to be attached to it.
3. Once the circuit is prepared, connect the different materials to the free terminals and observe the bulb brightness.
4. Change the bulb by a Multimeter and record the results.



QUESTIONS

1. Annotate your observations in the below table:

Material	Bulk's Brightness

2. Divide the materials you have used in good conductors, poor conductors and insulators. Which criterion have you used to do this classification?

3. Record the data (in volts) indicated by the multimeter:

Material	Voltage

Experiment 2: Attraction and repulsion of charges

OBJECTIVE

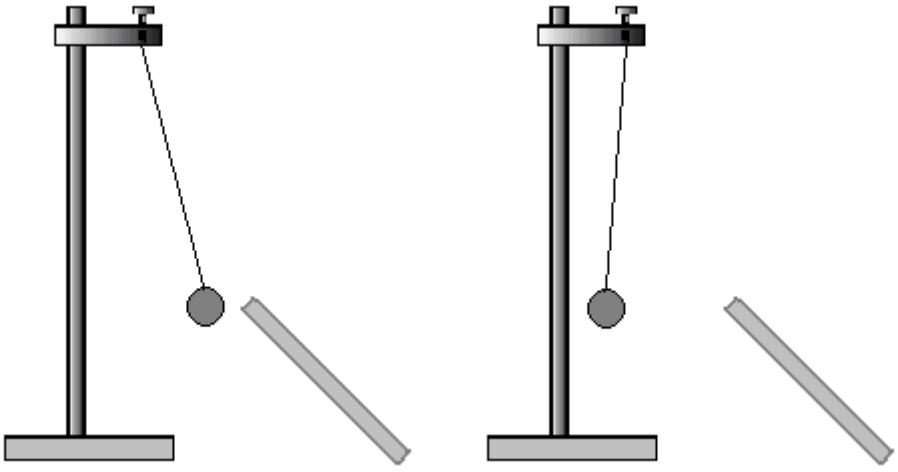
Observe the attraction between opposite charges and repulsion between like charges.

EQUIPMENT

Electroscope	Pith ball pendulum
Animal fur	Ebonite or plastic rod
Silk cloth	Glass rod
Balloon	Comb

PROCEDURE

1. Rub a plastic rod with animal fur. Touch the electroscope and record what you observe.
2. Rub a balloon on your hair and touch the electroscope previously charged. Record what you observe.
3. Repeat part (**2**) but touching the electroscope with a comb.
4. Rub a glass rod with silk cloth. Touch the electroscope and record what you observe.
5. Approach the plastic rod rubbed with animal fur to an uncharged pith ball pendulum. Observe that the pith ball is first attracted and then repelled.



6. Do the same that in part (**5**) but with a glass rod rubbed with silk cloth. Annotate your observations.
7. Approach the plastic rod rubbed with animal fur to the charged pith ball pendulum of part (**6**). Annotate your observations.
8. Approach the glass rod rubbed with silk cloth to the charged pith ball pendulum of part (**5**). Annotate your observations

QUESTIONS

1. Tell if the following statements are true or false. Change the false statements to the correct ones.

a) When the plastic rod is rubbed with animal fur the plastic rod and the animal fur became positively charged.

b) When the electroscope is touched with the charged plastic rod, their leaves separate because they both acquire positive charges.

c) When the balloon is rubbed with the animal fur, it acquires the same kind of charge that the plastic rod because the leaves of electroscope repel even more.

d) The type of charging that occurs when a glass rod is rubbed with a silk cloth is called electrification by contact.

e) The type of charging that occurs when a charged rod is brought close to a neutral pith ball is called electrification by induction.

f) In electrification by friction objects acquired the same kind of charge.

2. What type of charge acquire the comb when is rubbed with fur? Why?

3. Explain why the pith ball is first attracted and then repelled when approaching the rubbed plastic rod or the rubbed glass rod.

4. Have the rubbed glass rod and the rubbed plastic rod the same kind of charges? Explain the reasons for your answer.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Electrostatics	☐
Negative Charge	☐
Positive Charge	☐
Friction electrification	☐
Conduction electrification	☐
Induction electrification	☐
Conductor	☐
Insulator	☐
Electroscope	☐
Electrophorus	☐
Van der Graaff generator	☐

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I understand the concept of electrical charge.			
I know that like charges repel one another and unlike charges attract one another.			
I Know that when an object is charged by friction, the object acquires different charge than the material used to charge it.			
I Know that in the process of charging a neutral object by conduction, charges go from the charged to the uncharged object.			
I understand why an object charged by conduction has charges of the same sign that the charge object used to charge it.			
I understand the process used to charge an object by induction.			
I know the differences between conductors and insulators. .			
I know why a substance is conductor of electricity.			
I understand how an electroscope works.			
I know how to make an electroscope.			
I know how to guess the sign of unknown charges by using an electroscope.			
I understand how an electrophorus works.			
I know how to make an electrophorus.			
I know how a Van der Graaf generator works.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.