Static Electricity

Student Study and Analysis Sheet

Introduction

Most commonly during the winter season, when the air is drier, you are likely to experience triboelectric charging of objects on a frequent basis. Getting out of the car and reaching back to close the door, or removing a jacket made of synthetic fabric, can lead to a startling electric shock. Sometimes garments taken off in total darkness will give a dazzling display of sparks and glowing fabric. Static cling and other nuisance electrostatic charging has become more common due to the widespread use of synthetic fabrics and plastics, and most people have found ways of coping. For instance, when you get out of the car and reach for the door, let the metal key in your hand touch the door first. The spark will still be there, but not the tingle. These synthetic materials are good insulators and do not readily dissipate charge once it has been separated. The nature of triboelectrification is very complex, but we can make a beginning. Using the electroscope on the electrophorus as an indicator, try to determine the sign and amount of charge as you unroll some Scotch™ "Magic" tape. You should find the charge on the tape to be opposite to the charge on the rest of the roll if you are careful not to provide conductive paths to discharge them. In fact, two pieces of the tape will repel one another if you quickly bring them close together as soon as you have removed them from a weighted dispenser.

The electrophorus (Greek for "charge carrier") was invented by Johannes Wilcke and improved by Alessandro Volta over two hundred years ago, and it is still the favorite starting place for investigators who need a source of static charge and voltage. The electrode, that is, the plate, makes intimate contact with the tribocharged pad, but it actually charges by induction. A clear way of showing this is to bring the neutral plate to the charged pad, touch the plate briefly, and then lift the plate away by its handle. The electroscope helps to deduce what is happening and shows changes in the sign and amount of charge. If the pad is charged negatively as it attracts electrons from the cloth, the plate touching it will tend to repel negative charge to the opposite side of the plate. Touching this allows charge to be conducted to ground, and then the separated plate is strongly positive. It has been charged by induction. (To give the styrofoam pad a positive charge, try rubbing it with a plastic bread bag.)

> **Note:** *Because of its conductive properties, the piece of wool used as a rubbing cloth in these experiments will usually not retain a charge for very long because the charge leaks rapidly to ground through the body.*

If you bring the positive plate near your finger again, or near any object that can be a source of electrons, the plate will attract them, making a second spark. The air in the spark that jumps a few millimeters is ionized as the moving electrons knock other electrons off nearby air molecules. The ionized air emits light and sound. The energy for each capacitive spark drawn from the electroscope is actually supplied by the action of lifting the electrode off the pad, so lifting the electrode higher should give stronger sparks, and a stronger tingle if you become a part of the conducting path.

Lifting the plate should not change the electroscope indication because the constant charge simply redistributes itself as evenly as it can. A conductive ball would make the best electrode, and a plate with a sharp edge would be the worst. Charge distribution is influenced by the curvature of the body. This can easily be explored by taping a sharp needle or pin to the edge of the plate before trying all the things described above. There should be a corona discharge at the point where the charge concentrates so much that the air can no longer insulate the plate. If one listens closely as the plate is lifted, a soft, varied-pitch buzzing noise lasting just a few seconds may be heard. Some people have found ways to use this kind of discharge in place of loudspeakers, but it is not very portable. The corona stops after the voltage on the plate has been reduced below the breakdown threshold. If a small piece of antistatic plastic foam can be found (of the sort used for packaging EDS-sensitive electronic components—it's usually black), then the corona discharge can be largely suppressed simply by covering the sharp tip of the needle or pin.

It is interesting to consider the Triboelectric Series, an approximate list of common materials in the order of increasing work function. The term refers to the relative ease with which an electron can be stripped from an atom. In general, materials with higher work function will tend to appropriate electrons from materials of lower work function if they are brought into contact and then simply peeled apart. While some call this "friction electricity", it is more related to contact where bonds are formed and then not symmetrically broken when the surfaces are peeled apart. Rubbing does seem to help because most real surfaces are not flat against each other at the atomic level, the way a piece of tape might be. It should be noted that real materials are seldom pure, and they differ in finish, conductivity, and significant mechanical properties—even if they look identical—so the list will not let us make quantitative predictions with confidence. You will also find other lists that will not exactly agree with this one for similar reasons. It is best to work with materials that are far apart in the list.

At the positive (+) end of the series are materials of lower work function

Human Hands
Asbestos
Rabbit Fur
Glass
Mica
Human Hair
Nylon
Wool
Fur
Lead
Silk
Aluminum
Paper
Cotton (approximately in the middle)
Steel
Wood
Amber
Sealing Wax
Hard Rubber
Nickel, Copper
Brass, Silver
Gold, Platinum
Sulfur
Acetate, Rayon
Polyester
Styrene, Styrofoam
Orlon
Saran
Polyurethane
Polyethylene
Polypropylene
Vinyl, PVC
Teflon
Silicone Rubber

At the negative (–) end of the series are materials of higher work function

The need to protect sensitive electronic components and computer boards from electrostatic discharge during handling, shipping, and assembly provided the driving force for the development of an entire new class of antistatic packaging materials. Key developments in polymers—notably conductive polyethylene and sophisticated laminates with very thin metalized films—have created a multimillion dollar packaging industry. This enterprise undoubtedly saves many hundreds of millions of dollars each year for the electronic and computer industries, and it dwarfs all other commercial and industrial triboelectric abatement activity.

Interested investigators should certainly prowl the Web in search of other supporting information, the doings of the electrostatic society, and the thoughts of those who pioneered Xerography and ushered in the modern photocopier by harnessing static cling. (Did you know that at low humidities, paper is a surprisingly good insulator? On the other hand, above 60% RH, its surface resistance becomes low enough to interfere with paper handling and toner transfer processes inside many photocopiers.)

The Static Electricity Lab Activity uses simple materials that reliably work even in damp weather to show the basis for charge separation, charge storage, charge polarity, conductors, insulators, and the like. Charge is stored on an efficient electrophorus and illustrated in a quantitative way by a conductive ball that works both as an electroscope and also as a "bucket brigade" to carry charge to a waiting finger or other object. The flash of a neon lamp will identify the more negative of two objects, allowing the identification of polarity. A capped clear tube with central electrode and styrofoam beads of various sizes is used to study induced charge in various ways, as the beads are made to cling to the walls and then to the electrode by changing circumstances.

Objective

To determine the circumstance and limits for separating electric charge by the contact and rubbing of poor conductors. Sometimes called triboelectricity, contact electricity, or even friction electricity, this familiar source of static electric shock will be explored with the aid of a simple apparatus.

Materials Needed per Lab Group

1 Styrofoam Pad
1 Aluminum Plate
1 Styrofoam Cup with two holes
1 Plastic Straw slit at one end
1 Threaded and Conductive-Coated Balls
1 Piece of Wool Cloth
1 Neon Lamp
1 Capped Tube with electrode and beads

Shared Materials

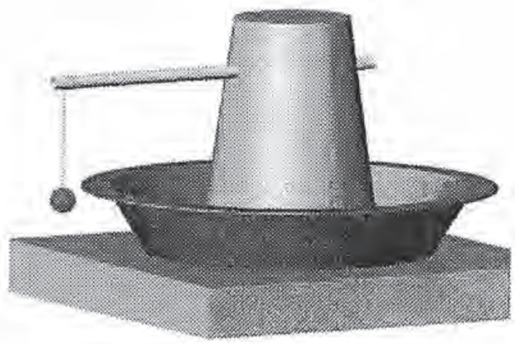
Scotch™ "Magic" Tape
Sharp Needle or Pin
Antistatic Plastic Foam
Electrostatic Shielding
Antistatic Bags

Procedure

Prepare the Electrophorus (Figure 1)

1. Invert the styrofoam cup in the center of the aluminum plate and tape it in place. This forms an insulated handle for moving the plate from place to place. Always use this handle.
2. Slide the plastic straw through the two holes, with the slit end outermost.
3. Hang the coated ball from the straw by passing the thread through the slit in the straw.
4. Adjust the position of the ball so that initially it is even with the edge of the plate and about an inch away.
5. Set the styrofoam pad in a convenient location, and rub the top of it briskly with the wool cloth for a full minute.
6. Using the handle, set the plate on the pad and notice what happens to the ball.

Figure 1



Charge the Electrophorus

1. Charge the styrofoam pad by rubbing it with the wool cloth.
2. Charge the plate by placing the plate on top of the charged pad. Briefly touch the edge of the plate with your finger. You may feel a shock or hear a snap. Remove the plate using only the styrofoam handle.
3. Discharge the pan by touching it. If the room is dark, you will see a spark. You may connect a neon lamp to discharge the plate (see below). Charging the pad once will suffice for several charges of the plate. For more spectacular discharges of the plate, lift it at least a foot above the pad.

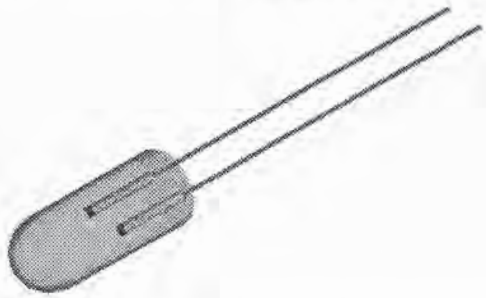
Charge Transport

1. The attached electroscope can be used to demonstrate the transport of electric charge. When the plate is first charged, it should induce the opposite charge in the hanging ball, which should attract the ball.
2. If the ball can touch the plate, charge will be shared by conduction, and now the same charge on the ball will cause it to be repelled from the plate.
3. If one carefully touches the ball with the tip of a finger that is held steadily in the right place, the ball will discharge, swing back, touch the plate, and then swing out again to touch the finger. The plate will be slowly discharged by this "bucket brigade" type of charge transport.

Polarity of Charges

1. The included neon lamps (Figure 2) can be used to show the sign of electrostatic charge. Connected in series, the lamps can also approximate the voltage of the charge, since each lamp requires about 75 volts to show the characteristic orange color of the glowing neon gas inside. For example, ten lamps in series would need about 750 volts to flash.

Figure 2

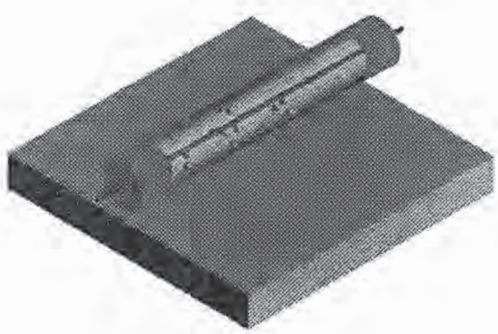


2. Determine the sign of the charges by holding one lead of the neon lamp in your fingers and touching the other lead to the charged object. Inside the lamp, you will see two metal electrodes. On closer examination, one of the electrodes will glow orange more than the other one which might not even glow at all, as long as more than 75 volts potential difference exists between the electrodes. The glowing electrode is connected to the more negative of the charge sources. In this case, you are one of the charge sources.
3. With two sources of charge, touch one lead to each charged object without touching either of them yourself. Again, the electrode connected to the more negatively charged object will glow. If used with energy sources other than electrostatic ones, a resistor of 39k will prevent the lamp from being destroyed.
4. Neon lamps have a negative temperature characteristic. Try touching one of the leads of the neon lamp to the plate on the charged electrophorus and to the coated ball.

Induced Charges

1. Charge the pad with the wool cloth and set the capped tube with electrode and balls on it (Figure 3).

Figure 3



2. Notice what happens when you do each of the following: bring a finger toward the tube, touch the electrode, pick up the tube, touch the electrode again, hold the electrode and bring the tube toward the pad, and finally touch the pad again.