Electrostatics

Objective

- To understand the basic phenomena of electric charges at rest.

Introduction

Atoms consist of a central nucleus made up of protons and neutrons surrounded by one or more electrons. While the nuclei of solids are essentially localized, some of the electrons may be free to move about. A substance which has as many electrons as it has protons is said to be electrically neutral. Dissimilar objects have different affinities for electrons. When two such objects, initially neutral, are rubbed together, the friction may cause electrons to pass from one to the other. After separation, neither object is neutral. Each is said to have been “charged by friction.” An isolated, electrified object becomes neutral again if its electron-proton balance is restored. A convenient means for accomplishing this is to connect the object to earth by means of a conductor, through which electrons readily travel. This process is called “grounding the body.” Since an electrified object is referred to as “charged,” grounding is also referred to as “discharging.”

Substances through which electrons do not move easily are called “non-conductors,” or “insulators.” Experiment has shown that when rubber and wool are rubbed together, electrons pass from the wool to the rubber. The electrons remain on the surface of the rubber—a non-conductor—where they were transferred.

Rubbing a metal rod with a wool cloth can also transfer electrons. This rod, however, is a conductor and electrons pass through it to the experimenter and then to the earth. People, made mostly of salt water, are good conductors, as well. Metal that is isolated, however, can be electrified. This can be demonstrated with an electroscope, which has a metal disk connected to a stem from which a thin metal rod hangs. An insulator prevents contact of these metal parts with the case, and consequently the earth.

Apparatus

- electroscope
- rubber and glass rods
- wool and silk cloth
- insulating handle with metal disk

Activity 1: Charging by Friction

1. Be sure the electroscope is discharged by touching the disk with your finger. Explain what happened and why you are convinced the electroscope is discharged.
2. **Prediction**: If you rub the disk of an electroscope with a wool cloth, what will be the state of the electroscope when you remove the cloth? Explain.

3. Gently and repeatedly rub the disk of the electroscope for a couple of minutes. Remove the cloth. Note any differences in the electroscope from its appearance before you rubbed.

4. Explain what, if anything, happened.

**Activity 2: Charging by Contact**

1. Discharge the electroscope as before.

2. Charge the metal disk mounted on the insulated handle by friction with the wool cloth.

3. Does anything occur in the electroscope when you bring the disk on the handle close to the disk on the electroscope without touching it?

4. **Prediction**: What will happen to the electroscope if you repeatedly touch its disk with a freshly charged object?

5. Touch the disk on the handle to the disk on the electroscope; rub the disk again with the wool cloth and again touch it to the disk on the electroscope; repeat this procedure two or three more times. Describe any changes to the electroscope.

6. Repeat the procedure above until the electroscope’s rod is at approximately a thirty degree angle with the stem.
Activity 3: Kinds of Electrification

1. Electrify one end of the rubber rod by wrapping the wool cloth around the rod, squeezing the wool against the rod, twisting the rod vigorously to ensure good contact, and separating the wool from the rod.

2. **Prediction:** What will happen when you bring the electrified end of the rubber rod toward, but not touching, the electroscope’s disk? What will happen if you do the same with the wool cloth?

3. Bring the charged end of the rubber rod toward the disk, but do not touch it. Record what happens.

4. Repeat step 3 with the wool cloth.

5. What differences were there between the trial with the rod and the trial with the cloth?

6. How would you account for these differences?

7. **Note:** By definition, the electrical state of the rubber after being rubbed by the wool is negative. That is, an object that has an excess of electrons is said to be negatively charged. Realize that this is only a convention.

8. If the rubber is said to be negatively charged, in what electrical state is the wool cloth?

9. How can an electroscope be used to determine the nature of any charge?
10. Rub the end of the glass rod with the silk cloth and determine the charge of each after they are separated.

11. What is the charge on the glass rod? On the silk cloth?

**Activity 4: Action of the Electroscope**

1. **Discussion:** Two facts explain the rise or fall of the rod of an electroscope: (a) Like charges repel (unlike charges attract); and (b) Free electrons move about in a conductor when an electric force acts upon them.

2. Discharge the electroscope.

3. **Prediction:** What will happen when you bring the charged rubber rod near the discharged electroscope? What will happen if you do the same with the wool cloth?

4. Test your predictions; record the results; try to explain them. (It may be difficult to see the effect with the cloth.)

5. When the rubber rod approaches the disk, which way do the free electrons in the metal of the electroscope move (up toward the disk or down toward the rod)?

6. Do the rod and stem of the electroscope now become positive or negative?

7. In Activity 3, the electroscope was negatively charged before either the rod or the wool was brought toward the disk. For the case of the rod, in which direction do the free electrons in the electroscope move? Does the electron displacement increase or decrease the electrostatic force separating the rod from the stem?
Activity 5: Charging by Induction

1. Discharge the electroscope.

2. **Prediction:** What will be the effect on the electroscope if you perform the following experiment: while grounding the electroscope with your finger, bring an electrified rubber rod near the disk, then take away your finger and then the rod (in that order)?

3. Carry out the experiment and describe the result.

4. Explain the result and why your prediction agreed or disagreed with it.

5. **Prediction:** Note that no electrons moved between the rod and the electroscope. What charge has been induced on the electroscope?

6. Test your prediction with the negatively charged rubber rod and the positively charged wool.

7. Does the test verify or contradict your prediction? Explain.

8. Draw a series of diagrams illustrating the charging of the electroscope by induction.