

# Faraday Cage

P6-3370



## BACKGROUND:

Named after the English chemist and physicist Michael Faraday, this apparatus is designed to demonstrate the principles of static electricity, and to allow the student to investigate and manipulate the electrostatic phenomena.

## KIT CONTENTS:

- 1 each Faraday Cage with Cover
- 1 each insulated base for Faraday Cage
- 1 each insulated pinpoint discharger

The Faraday Cage apparatus consists of an iron mesh cylinder big enough to accommodate an electroscope. This cylinder has two metal caps for both ends.

## CAUTION:

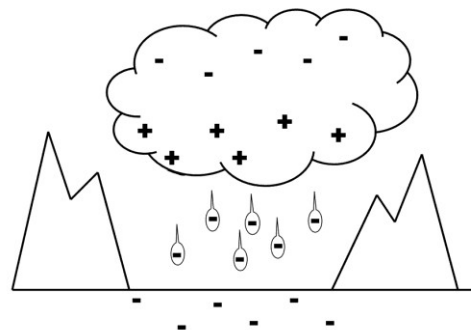
The materials in this kit should be protected from salt spray, chemical fumes, and perspiration, which may coat them with a thin film of moisture. This would prevent the proper conduction of charge. Before use it is advisable that the materials be cleaned gently with distilled water, and allowed to dry completely. If the humidity is very high there may be problems with lint. Particles of lint on the surfaces will act as discharge points, making use difficult. Also, use near ionizing sources should be avoided. Use near an open flame or a radiation source will produce charges that will interfere with the proper operation of the Faraday Cage.

## BACKGROUND ON STATIC ELECTRICITY:

Static electricity has been known for many years, and was one of the first sources of electricity to be investigated. Benjamin Franklin performed his early experiments in electricity with static electricity, and the Leyden jar was developed as a means of storing and accumulating static electricity.

With the development of current electricity, static electricity became mostly a matter of historical interest. However, recent developments of liquid crystal displays, medical X-ray imaging and xerographic copying have revived interest in this phenomenon.

The most easily observed electrostatic effect is lightning. Rapid air movement causes a slight static charge to accumulate on the ground and nearby objects. A similar but opposite charge accumulates in the air. While the charge caused by air movement is slight, there is a lot of air, and a large area for the accumulating charge. When the difference in the charge becomes great enough, the two charges (positive and negative) discharge across the gap between them, and the result is a bolt of lightning.



An equally common effect, but one which most people do not realize is electrostatic, is the xerographic copier. In this case a special type of material is used, which is nonconducting in darkness but conductive when exposed to light. While in the dark the material is charged with static electricity. When it is exposed to light the areas exposed lose the charge, while those exposed retain the charge. After exposure to light the plate is sprayed with a fine powder of oppositely charged dry ink (toner), which adheres to the areas of the plate that retained a charge by electrostatic attraction. Finally, a sheet of paper, which is also charged, is placed on the plate, and the toner is transferred to the paper. The paper is then heated briefly to make the toner adhere permanently. The excess toner is scraped off of the plate, and the entire plate is exposed to light to remove any remaining charge.

### Theory of Static Electricity

The word “Static” as in “Static Electricity” means at rest. This is, however, a misleading name because static electricity does indeed move. The name static electricity differentiates between current electricity, which is produced by using a magnetic field to force the electrons over a conductor. In static electricity, the electrons are physically pushed from one place to another. This causes a temporary uneven distribution of electrons over an object. Because the natural tendency of objects is to remain in a neutral state, the electrons strive to regain that neutral balance in the object by slowly leaking off or quickly jumping to another object with fewer electrons, which causes a small spark.

The term *conductor* is used to refer to materials that will allow electrons to travel over it easily. Some materials act as better conductors than others, providing an easier path for the electrons. The term *insulator* refers to a material that opposes the travel of electrons. A good insulator prevents almost all passage of electrons. The air however, which is usually considered an insulator, can conduct electricity slightly depending on the moisture in the air. This accounts for the fact that electrons can escape from even the best insulators by discharging through the air. The word *electron* comes from the Greek word which means amber. At the time, the Greeks discovered the effects of static electricity by rubbing amber with a cloth. They thought that amber was the only material that exhibited this phenomenon. When other materials were discovered that showed similar properties they were referred to as having the amber effect or *electrica*.

It is important to remember when experimenting with static electricity that like charges repel one another and unlike charges attract one another. The electrons can transfer from one highly charged object to one that is less charged because the higher concentration of negative electrons is attracted to the object that is more positive in state.

Pushing electrons along a conducting media with a magnetic field generates current electricity. Static electricity is a non-moving electrical charge. It is created by mechanically moving electrons from one place to another. If some material has free electrons (as most do) they will in general be evenly distributed on the surface along with positive charges in such a way the overall charge of the object is neutral. By rubbing two such materials together, however, it is possible to mechanically redistribute the electrons so they are, temporarily, unevenly distributed. When this happens the object had a slight negative charge where the electrons are concentrated.

If the two objects have different amounts of free electrons, and since electrons (like charges) repel each other, some of the electrons from the object with more electrons will be transferred to the other object. As long as the two objects are in contact, the overall charge will remain neutral. However, when the two objects are separated, one will now have more electrons than it started out with, and the other will have less. The result is a negative charge on the one with more electrons and a positive charge on the one with less. This is what happens when you walk across a floor (especially during the winter when there is not enough water in the air to conduct charges). As you walk you slowly transfer electrons from the carpet to your shoes, and the electrons move as far away from the carpet as possible, to your fingers. When you then touch the grounded object (such as a light switch) the electrons move to the switch, so that your body is once again neutral. You get a shock as the electrons jump from your finger to the switch!

## ACTIVITIES:

### Activity One: Using your Faraday Cage

**Purpose:** To demonstrate that electrostatic charge resides on the outer surface of the conductor enclosing some space. There is no charge in the enclosed space.

In addition to the Faraday Cage, you will need an electrophorus, proof plane and two foil leaf electroscopes.

**Precautions:** To get good results, the room where you experiment should be dry. The surface of the apparatus must be clean. The experiment performs better in dry weather.

First, set up the Faraday cage apparatus with its metal caps on an insulating surface. Place one electroscope inside the cage by removing the top cap. Replace the cap. Now charge the electrophorus. Transfer the charge to the cage with the help of a proof plane. For this, touch the proof plane to the ball of the electrophorus and touch the cage with the proof plane. Do this repeatedly. Charge the electrophorus again and again and transfer the charge to several places on the cage. Bring the second electroscope near the outside of the cage. The electroscope will show charge. The electroscope placed inside the cage does not show any charge at any stage in the experiment.

In the above experiment, when the outside electroscope is showing charge, touch the mesh surface with the head of the insulated pin discharger with the point of the pin pointing outwards. The leaves of the electroscope will fall down showing discharge from the pinpoint.

If the electroscope showing charge near the surface of the cylinder is moved up to the edge of the cylinder, it will show more divergence showing that charge is concentrated at the edge of the conductor cage. Of course you will remove the top cap when touching the edge with the electroscope ball or disk.

## Conclusions:

1. The charge remains on the outside of a conductor and none on the inside.
2. The sharp points discharge a charged conductor quickly.
3. The charge is concentrated at the edges of a conductor.

**Note:** Two electroscopes have been used to show contrast in them at the same time. One electroscope can only be used inside or outside by turn.

## Activity Two: Creating Faraday's Ice Pail

In this activity you will need a metal can, a disk terminal, two foil leaf electroscopes and a transfer ball.

First, place the metal can on the disk terminal of one electroscope. Make certain the electroscope is discharged. Transfer the charge to the transfer ball and lower it into the can. Note that the foil leaves show a charge. Remove the ball and note that the foil leaves are no longer charged. Touch the transfer ball to the inside of the can, and note that the leaves still show a charge. Now discharge the transfer ball. Show that it has no charge by touching it to the terminal of the other electroscope. Touch the transfer ball to the inside of the can and attempt to transfer the charge to the electroscope. Note that, although the can as a whole has a charge, there seems to be no charge on the inside of the can.



Discharge the transfer ball and attempt to transfer a charge from the outside of the can to the other electroscope. It appears that there is some charge on the outside of the can, but none on the inside. How is that possible?

When the transfer ball is first inserted in the can, it drives the similar charges both to the electroscope leaves and to the outside of the can. When the transfer ball is touched to the inside of the can it neutralizes the charges inside the can, but not those on the foil leaves or outside of the can. Therefore, there is no charge on the inside of the can to be transferred later on, but there is still a charge on the outside and this can be transferred to the other electroscope

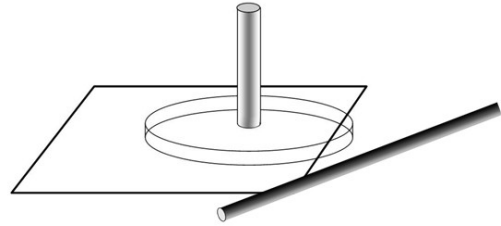
## ADDITIONAL ACTIVITIES FOR THE GENERATION OF STATIC ELECTRICITY:

### Activity One: The Electrophorus

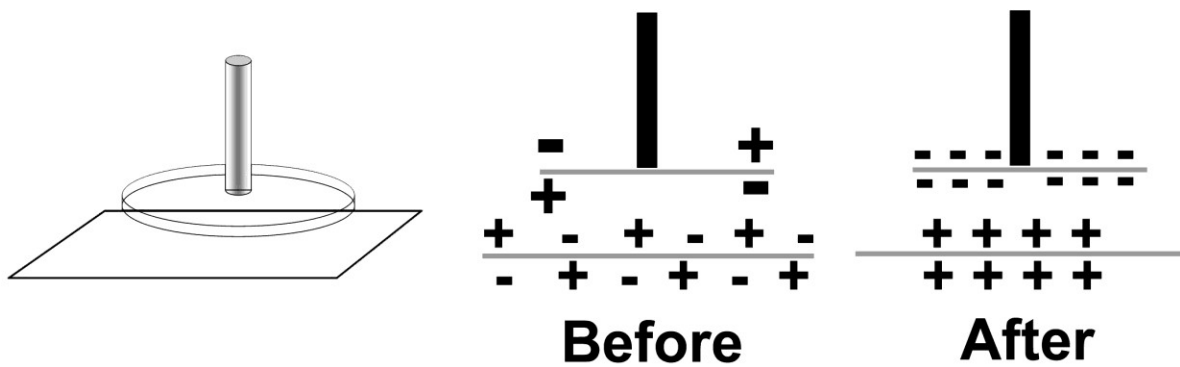
**Note:** In the following activity the polyethylene rod or some other type of plastic rod or strip is used to produce the initial charge. It may be instructive to have the students try many materials to see if there is any difference in the amount of charge that each material will create. You will also need a flat acrylic plate, flat metal plate, acrylic sheet, various cloth materials and a neon bulb.

The *electrophorus*, which means “electric carrier”, is a very simple and easy to make electrostatic generator. It is just a flat acrylic plate that is rubbed with a cloth or other material by hand. This builds up static in the plate, which can then be transferred to a flat metal plate that has an insulated handle. Different materials rubbed on the acrylic plate will have different effects.

Place an acrylic sheet on a flat surface and rub it briskly with the polyethylene rod. Do not touch the sheet with your hand. It is easiest if the sheet is placed at the edge of a desk or table, and the rod is held so that the handle is over the edge. When a charge has been built up on the sheet, place the electrophorus on the sheet with the handle in the air. Some of the electrons on the charge sheet will move to the neutral electrophorus, giving it a charge. If there is sufficient charge and you bring the electrophorus away from the sheet and touch it with your finger you should feel or hear a small spark as the charge jumps the gap from the electrophorus to your finger.



Recharge the sheet and use it to charge the electrophorus. This time touch a small neon bulb to the electrophorus. If the charge is sufficient you should see the bulb glow as the charge is transferred.

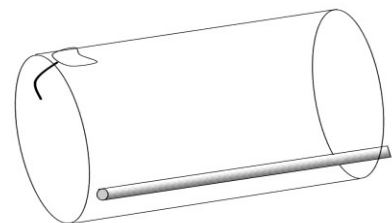


## Activity Two: The Electroscope

The electroscope is a device used for detecting a difference in electrical potential of an object. The word scope means “to see” and an electroscope is designed to allow you to see the presence or absence of an electrical charge.

**Note:** This activity requires various friction rods of different materials, including solid glass, nylon, acrylic, polystyrene, PVC and polyethylene. You will also need an acetate cloth, polyethylene bag and a balloon.

To begin you will need some way to test the electrostatic charges. Usually for this you will use some sort of electroscope. You can use any type or make one using a drinking glass or a beaker and tape cotton thread to it as shown. This cotton thread will act as a simple electroscope. That is, it will be used to determine the presence of an electric charge.



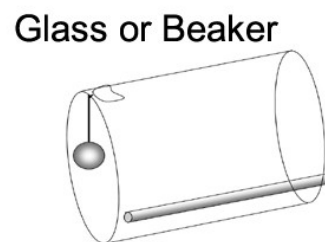
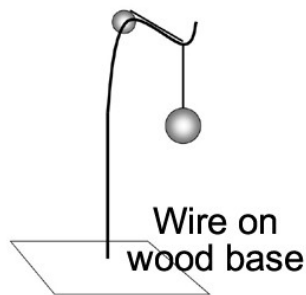
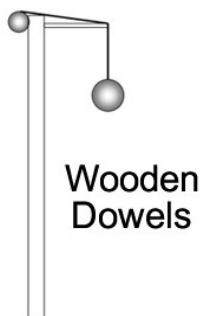
Before you test a rod, bring each up against a grounded item, such as a metal desk, radiator or water pipe. This will help discharge the items before testing them with a different material.

Now, take each of your friction rods and, one at a time, test each with acetate cloth and polyethylene bag by rubbing them on the rod. Bring the item being tested close to the thread and watch the thread's movement. Note in the chart below what type of rod was used, what type of pad was used and, using a scale of 1 to 5 with 5 being the greatest attraction to the thread, what were the results.

ROD TYPE	ACETATE	POLYETHYLENE
	Attracted to the thread on a scale of 1 to 5	
Solid Glass		
Nylon		
Acrylic		
Polystyrene		
PVC		
Polyethylene		

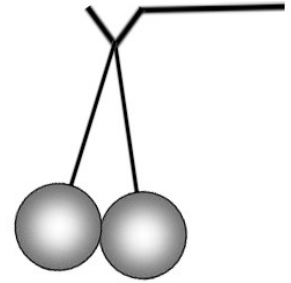
### Activity Three: The Pith Ball Electroscope, Attraction and Repulsion

An electroscope works because of the nature of electrons. More simply because opposite charges attract and the same charges repel one another. If an object that is highly charged with negative charged atoms (electrons) is brought near to two aluminum painted cork balls (used to be made from pith) hanging side by side, the positive atoms on the balls will be attracted towards that object.



This will cause them to swing in the direction of the object being tested. If the object touches the balls, some of the electrons will be transferred to the balls. This makes both balls negatively charged which, in turn, caused the balls to repel one another. The more negative they are the more they will push each other away. This gives you a visual of the strength of the present charge.

Take a cork ball set (or pith ball set) and suspend one ball by wrapping the other around an insulated hanger. This can be a hook on a wooden dowel, a piece of wire on an insulated base, or you can use a glass as in the previous electroscope (see illustration above). Charge the electrophorus and bring it near the ball. Since the ball is neutral, it has both a positive and a negative charge. As the electrophorus gets near, the negative charges on it attract the positives on the ball, and repel the negative charges. This causes the negative charges to move to the far side of the ball, and the positive charges to move to the near side.

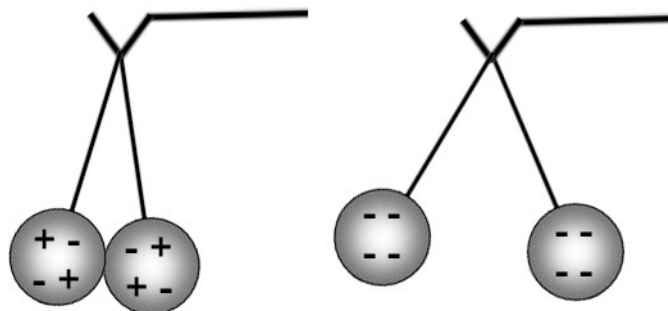


Since the opposite charges attract, the side of the ball nearest the electrophorus will be attracted to the electrophorus and the ball will swing that way.

If the charge is strong enough and the two objects are near enough, the ball will actually touch the electrophorus. When this happens some of the negative charge on the electrophorus will be transferred to the ball and both will become negatively charged. As soon as this happens the like charges will repel each other and the ball will swing away from the electrophorus.

You may also use a PVC rod with the attached metal ball as a transfer apparatus. You will probably have even better results because the PVC rod acts as an insulator.

Next, take the cork balls (one on each end of a string) and suspend them from an insulated hanger so that they are free to move in any direction. Charge the transfer ball and move it near the balls. The balls should move away from the transfer ball, just as the cork ball did. Touch one of the balls with the transfer ball, and watch what happens. The ball that was touched will swing away from the transfer ball and will touch the other ball. Each time some of the negative charge is transferred, so that both balls end up with a negative charge. If you recharge the transfer ball, and touch one of the balls again, more charge will be transferred and the two balls repel each other more. Eventually, you will find it impossible to bring the transfer ball in contact with either of the balls, and they will not be able to touch each other.



## Activity Four: The Flask Electroscope



A very common type of electroscope and one that has been around for a long time is the flask electroscope (*Arbor Scientific P6-1156*). This item can be very sensitive and, because it is enclosed within a glass housing, it is not prone to being affected by air currents in the room.

Rather than using pith balls or cork balls for indicating the presence of charges, it uses very thin metal foil leaves. Another big difference is the way that the charge is induced on to these leaves. Rather than the object being tested coming in direct contact with the leaves, the charge is introduced to a metal post to which the leaves are attached. The charge is then transferred from the post to the leaves. The foil leaves then act in a similar manner to the cork balls.

**Note:** The following flask electroscope activities require two flask electroscopes, a rubber, plastic and glass rod, a piece of wool and silk cloth, as well as two metal disk terminals for using in place of the metal terminal ball found at the top of a standard flask electroscope. You will also need an acrylic sheet and a neon bulb.

First, set both flask electroscopes up with metal balls on the top of their post. Discharge the electroscope by touching the balls with your hand or against a metal disk or similar object. When the electroscopes are discharged both leaves should hang straight down.

Take a rubber or plastic rod and rub it with a piece of wool cloth or similar material. When the rod is rubbed with the material, electrons are rubbed off the cloth and onto the rod. When a rod is brought near the ball (but not touching) the electrons that are already present on the rod are forced toward the leaves. This is due to the repulsion of similar charges. When both leaves have an over abundance of electrons they repel one another causing them to separate from one another. When the rod is removed the leaves should return to their earlier state.

Now bring the rod back to the ball but this time actually touch the ball. This time you should find that the leaves remain diverged when you remove the rod. This is because some of the electrons from the rod transfer to the post, which remains on the rod and leaves after you take the rod away. The electroscope will remain in this state until it is discharged. This can happen by touching the ball to something else that will attract some of the excess electrons or by leaking through the air. The time it takes to leak and return back to a normal state depends on the amount of charge and the humidity of the environment.

Now remove the balls from the electroscopes and replace them with metal disks. With the plates touching, charge one as in the illustration. Both electroscopes should now show a charge. Discharge one of the electroscopes by touching it with your hand. You should see that both discharge showing how the charges can transfer from one to the other. Finally, charge one of the electroscopes and then bring the charged electroscope to the other and allow the plates to touch again. You will find that some of the charge will transfer to the second electroscope. The movement of the foil leaves in the second electroscope will indicate this.

By using a glass rod rubbed with silk, you can generate an excess of positive charge on the rod. You will find that the electroscope will respond in the same way.

Next, take the electroscope and discharge it (to remove any residual charge) by touching it with your finger. The leaves should be hanging nearly straight down with only a small angle between them. Charge the electrophorus on the sheet, and bring it CLOSE to the electroscope. Do not touch the terminal! The leaves of the electroscope should move far away from each other slightly. The stronger the charge on the electrophorus the more they should repel each other. As you move the electrophorus away from the electroscope the leaves should return to a neutral state. Why does this happen? The high charge on the electrophorus (negative) repelled some positive charges on the terminal of the electroscope. The only place these positive charges could go was to the leaves of the electroscope. Since the two leaves then had the same charge, and since like charges repel each other, the leaves moved away from each other. When the electrophorus was removed, the positive charges could go back, returning the electroscope to a neutral state.

Again charge the electrophorus. This time touch the plate to the terminal of the electroscope. The leaves should move apart. However, this time the charge is due to an actual transfer of electrons, so it remains even when the electrophorus is removed. If this is repeated several times it is possible to build up a relatively strong charge on the electroscope, so that the leaves are standing well apart from each other. To return the electroscope to the uncharged state, touch the terminal with your finger. Charge it again, but this time discharge it by touching it with a neon bulb. If the charge was strong enough the bulb should light up briefly.

Charge an acrylic sheet again using the polyethylene rod. Take the transfer ball and rub it over the sheet, then touch it to the terminal of the electroscope. Repeat this several times, building a stronger charge on the electroscope. Note that each time you rub the ball over the sheet you are collecting more electrons, which are transferred to the electroscope. This is the mechanical transfer of static charge. This cannot be done with current electricity.

### **Activity Five: Point Discharge and a Flask Electroscope**

**Note:** This activity requires one flask electroscope and a discharge point.

To begin, discharge one of the flask electroscopes. Charge the transfer ball and move it near the electroscope. The leaves should deflect, showing an induced charge. Keeping the ball away from the electroscope, touch it with the back of the point. Now move the ball near the electroscope. This time the leaves should not move much, if at all. Obviously, the charge has been transferred to the point. Move it near the electroscope. Again the leaves will not move, showing that the point has no charge. Where did the charge go? Try one more thing. Charge the transfer ball and hold it near the electroscope. Now aim the sharp point at the disk of the electroscope and touch the transfer ball to the other end of the point. This time the charge should move to the electroscope, and some should remain even after the transfer ball and point are removed. Apparently the charge on a point is rapidly transferred to the air, and if the electroscope is near enough the charge will go there. This is the principle behind lightning rods. The idea is not so much to attract lightning to a particular point as to remove as much charge as possible from the building the lightning rod is attached to.

## **Activity Six: Induced Charge and Flask Electroscopes**

**Note:** This activity requires two flask electroscopes and two metal disk terminals.

To begin, remove the ball terminals from the electroscopes and replace them with disk terminals. Place the two electroscopes so that the disks are touching. Be certain that the two electroscopes are discharged. Charge the transfer ball and bring it close to the far side of one of the electroscopes. Note that both will show a charge. Being careful not to touch either of the disks, slide the two electroscopes apart. Move the transfer ball away. Both the electroscopes should now show a charge. Recharge the transfer ball and touch the terminal of one of the electroscopes. If that electroscope was negatively charged the leaves should move farther apart. If, on the other hand, it was positively charged, the leaves should move together, showing that the positive charge has been neutralized. Why are the two charged when there was no contact with the transfer ball, and why are they oppositely charged?

When the two were touching, they acted as one object. Therefore, when the transfer ball was moved near one edge, the negative charges on the combined plates were repelled from the transfer ball and moved to the far edge of the far electroscope. The positive charges were attracted to the transfer ball, and they moved to the near side of the near electroscope. While they were in this state the connection between them was broken, and when the transfer ball was removed it was impossible for the charges to move back to their original position. This resulted in an excess of positive charges on one electroscope, and an excess of negative on the other. Both, however, were charged so that the foil leaves were repelled.

### **RELATED PRODUCTS:**

**Flask Form Electroscope with Gold Foil Leaves (P6-1156)**

**Friction Rod Kit (P6-1600)**

**Hand Crank Van de Graaff Generator (P6-3400)**

**Coated Pith Balls (P6-1650)**

