615-3085 (10-091) Electrostatic Demonstration Kit

• Experiments
• Applications

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Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

Maintenance:

For best results, maintain these kit materials between each use.

1. Protect insulating materials from salt spray, chemical flames and perspiration. They coat them with a film of moisture which conducts away electric charges, affecting your experiments. You can remove any moisture film buildup with a rinse of distilled water.

2. Your experiments are BEST performed in a dry room. Avoid handling the material with moist hands.

3. At high humidities (over 80%), lint strands may cause short circuits or act as discharge points. If using an electrophorus, note that damp lint diminishes the potential of metal surfaces and makes them less effective. *See Page 11 for a list common materials and their effectiveness as charge generators.*

4. Watch for radiation, open flames etc. that might ionize the nearby air. These will slowly discharge the bodies you have charged and are testing.

Product Description:

See drawings and photos on next page.

• **Proof plane or Transfer Ball**- to "move" charges from the generator body to other bodies. Hold by plastic (insulator) handle. Ball "carries" charge.

• **Friction Rods** (polystyrene, acrylic, glass, nylon, PVC and polyethylene) and **Friction Surfaces** (acetate cloth, polyethylene film) are basic materials for generating electrical charges by rubbing rod against surface. (Additional material like *hard rubber comb, flannel/wool/silk cloth* can be added.

• **Conductive coated ball** has a hook to suspend with a piece of thread or fishline. Use it to detect charges and to study attraction and repulsion between charges (that is, between ball and charged bodies.)

• **Neon Lamp** helps detect presence of electrical charges. The brightness of its glow tells the intensity of electrostatic fields.

• With the **electrophorus** you can generate, store and transfer small quantities of electrostatic charges. Electrophorus consists of a metal disc with vinyl handle and acrylic charge plate.

• **Pith Balls** are lightweight masses that you hang from strings and use for demonstrating repulsion from or attraction to charged bodies.

• An **Electroscope** has vanes, a pair of thin metal foil leaves sensitive to electrostatic charges. They are connected together at one end to they spread apart (repel each other) or collapse (come close together.) The vanes are enclosed in a 250 ml flask and are hung on 4 brass hooks by means of holes at one end. The hanger connects to a short metal rod which passes through (and ends outside of) an insulating stopper that closes the mouth of the flask. This permits the metal ball terminal to be placed on the flask stopper, so it is in direct contact with the rod end; or the metal disc terminal to be screwed on to the rod end. This provides a direct conductive channel to any electric charge landing on the terminal, all the way to the foil leaves. *[Note: When the leaves are charged, they spread apart because of similar charges on both leaves. Otherwise, in their neutral state, they remain collapsed.]*

An **electrophorus** is a metal disc with insulating handle.

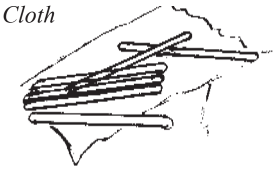
A **Faraday Cage** is an insulated metal cage. If charged, the charges on the outside repel one another and get as far away from one another as possible. An electroscope inside the cage will not get charged.

Theory:

What is electricity? It is, as we know today, a *flow* of electrons between two points (of a conducting body) much like the flow of liquids from a higher to a lower level.

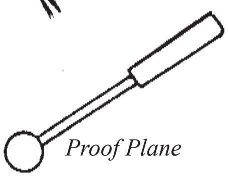
What are electrons? They are tiny particles carrying an electric charge. All bodies contain electrons in their atoms. Even though the electrons are charged particles, the atoms and the bodies which they make up are normally electrically neutral (uncharged.) This is because each atom holds its electrons revolving around a nucleus which contains an equal number of particles called protons. Since protons carry the oppo--site kind of charge as electrons carry, the atom as a whole remains neutral or uncharged. Therefore the bodies are neutral or uncharged in their normal state. Since by convention we think of electrons as carrying a negative charge, protons are electrically positive.

Rods and Cloth



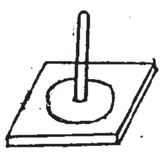
Neon Lamp

Conductive Ball



Proof Plane

Pith Ball, suspended



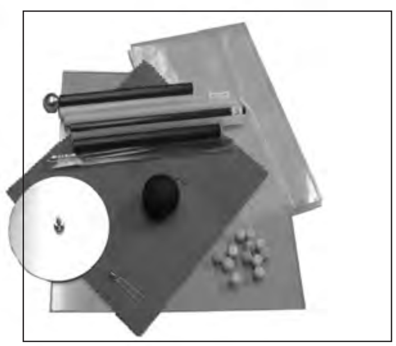
Electrophorus

Mounted Point

Faraday Cage, point, covers

Stand for Cage

Ice Pail



Electroscope Assembly, flasks and terminals

What is static electricity?

All matter is formed from positively charged nuclei and negatively charged electrons. A body with possess equal numbers of positive and negative charges is electrically neutral.

A body which more negatively charged electrons than positive charges to complement them is electrically negative. A body with fewer negative charges than positive would be termed positive since positive charges predominate. Except under rare circumstances, only the electrons flow. They flow away from a negative charge and toward a positive charge.

How does static electricity differ from current electricity?

Static electricity resembles water in a lake, current electricity resembles water in a river. Provide a channel and a lake will flow as much as the channel permits and as long as the supply lasts.

Static means to stand still. Static electricity is an electric charge which remains stationary. Provide a channel for its flow and it can become current electricity.

Experiment 1:
Friction Generates Electrical Charges

Additional Items Needed:
- Lightweight materials

(Paper, straw, feathers etc.)

Kit Components Needed:
- Friction rods
- Friction surfaces

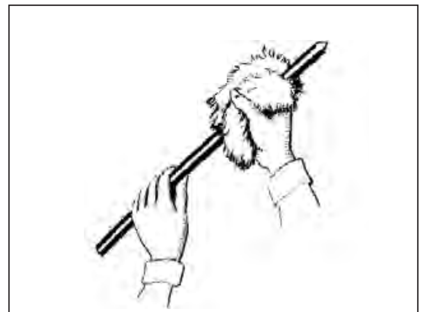


Figure 1

Procedure:
1. Choose a friction road and surface (for example, acrylic rod and acetate cloth.)
2. Cut out small bits of lightweight paper (or straw, packing material, feathers etc.) and spread them on the table.
3. Hold one end of rod and rub the other end with fabric. (*Figure 1)*
4. Bring rubbed end close to the material on the table.
5. Watch the bits fly and stick to the rod! Experiment with other rods and surfaces.

Further applications:
- Different students can use different rods and surfaces. Compare cases!
- For **older students,** use uniform paper cut outs (from a hole puncher) in order to see if the rods pick up equal amounts of material when rubbed more.
- Plot a **graph** with the number of paper pieces (Y-axis) against the length of time (or number of rubs received.

Discussion:

Why do rubbed rods behave this way? Because the rods become charged by friction and attract lightweight material electrostatically. *See Experiment 3.*

How do the rods become charged? All matter has a fraction of its electrons in a relatively loosely held state. When bodies touch each other or come into close contact by rubbing, the surface electrons from one body "get loose" and move to the other surface. The bodies are no longer neutral; the one which gains electrons is "negatively charged" and the other body which has lost electrons is positively charged.

Different materials have different affinities for gaining or losing electrons. Silk gains electrons when rubbed against glass and leaves it positively charged. Fur, flannel and wool lose electrons and charge amber or hard rubber negatively.

Frictional generation of electric charges was how electricity was accidentally discovered by the ancient Greek philosopher Thales 25 centuries ago. He observed that amber (*Elektron* in Greek) attracted light material like straw and feathers after being rubbed with fur. He thought amber (electron) was lost in the fur, but today we know that amber draws electrons from the fur to become negatively charged.

In generating electric charges, friction does not create more electrons. Electrons simply move between surfaces, keeping their total number the same. Electrons get redistributed and are not created or destroyed.

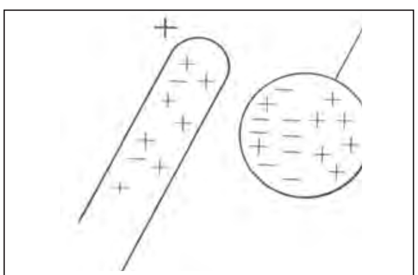


Figure 2 -Attracting an Uncharged Body. Why does the rod attract the ball even though the ball is not charged? The negatively charged side, being closer to the rod, is attracted by the rod more strongly than the positive side of the ball is repelled by it.

Experiment 2:
Charged Bodies Can Be Discharged

Additional Items Needed:
- Rods
- Pieces of paper, straw
- Metal surface

Kit Components Needed:
- Friction rods
- Friction surfaces

Procedure:

1. Take the charged rod, touch with your finger or to a metal surface (i.e. door knob.)

2. Carry the rod to pieces of paper (or straw, feather etc.) as before. Use **new** pieces of paper for best results!

3. The rod now cannot pick up material. It has *lost* its charge.

4. Compare cases using different combinations of rods and surfaces. In particular, use a positively charged rod (glass rubbed against silk) and a negatively charged rod (acrylic rubbed against wool or fur.)

5. Both kinds of charges can be removed by discharging.

Discussion:

In charging, there is redistribution of electrons between two bodies so one is positive while the other is negative. Discharging involves redistribution of electrons in which the charged bodies become neutral.

During discharge, electrons move between bodies through a transporting medium. They use your body or door knob to be transported - **to** the ground if your rod is negatively charged, or **from** the ground if positive.

Certain substances are better transporters or **conductors** of electrons than others. Metals are good conductors. The rods and surfaces in these experiments are not. They are **insulators.**

There is electrostatic cling from friction when you rub against car seats, walk with shoes on carpets or in clothes when they rub against each other in a dryer.

The "shock" you get when touching a doorknob or car door is because these objects are discharging the built-up charge through you.

Spark is discharge through ionized air.

Experiment 3:
Like Charges Repel; Unlike Charges Attract

Kit Components Needed:
- Charged Rods
- Fishline
- Stand
- Pith Balls (*Procedure 3*)
- Graphite Ball (*Procedure 4)*
- Electrophorus (*Procedure 4)*

Procedure 1:
1. Charge acrylic rod negatively by rubbing it against acetate cloth.
2. Suspend it by a fishline or string from a stand or high surface.
3. Charge another acrylic rod negatively and bring its end near the charged end of the rod.
4. Observe that the first rod swings away from the charged end of the other (*Fig. 3*). The two negative charges **repel** each other.

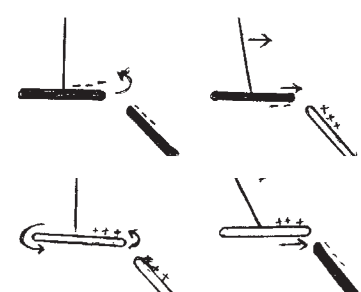


Figure 3 - A. 2 negative rods swing away from each other B. Negative rod pulled toward positive. C. Positive rod pulled away from positive. D). Positive rod pulled toward negative.

5. Bring positive rod (glass rubbed with silk) toward charged end of suspended rod.

6. Watch as it is pulled toward the other. A positive charge **attracts** a negative one.

7. Suspend the charged glass rod and bring another charged glass rod close to the first one. They should repel each other. Two positive charges also repel each other. **Like charges repel while unlike charges attract each other.**

Procedure 2:

Perform the following variation:

1. Instead of a charged rod, suspend a pithball (see *Fig. 4*)
2. Bring a negatively charged acrylic rod or positively charged glass rod close to it. Observe that the ball is attracted to the rod.
3. Touch the ball with the rod.
4. Watch the ball repel the rod.
5. Move the rod close. You will be chasing the pith ball!

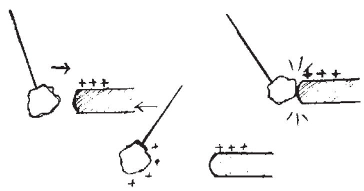


Figure 4

Procedure 3:

1. Bring two rods, one of them charged (either positively or negatively), the other uncharged, close to a suspended pith ball. (*Figure 5*)

Approach it from opposite sides simultaneously. (Uncharge pith ball by touching it with fingers or wall before you begin.)

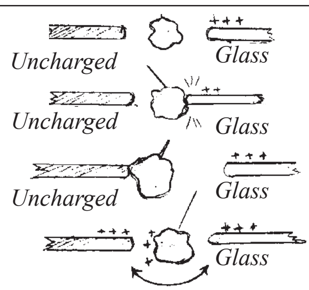


Figure 5

2. Let the ball be attracted to the charged rod. Then touch it.
3. The ball will be repelled by the charged rod, as before.
4. Let the ball touch the other (uncharged) rod on the other side. Watch what happens. It bounces off. And if it now touches the first rod, it bounces off it too! You can actually keep the ball going back and forth between the two!

Procedure 4:

Show the same effects as in Procedure 2 by using the conductive ball instead of the pith ball and an electrophorus in place of charged rods. See *Fig. 6.*

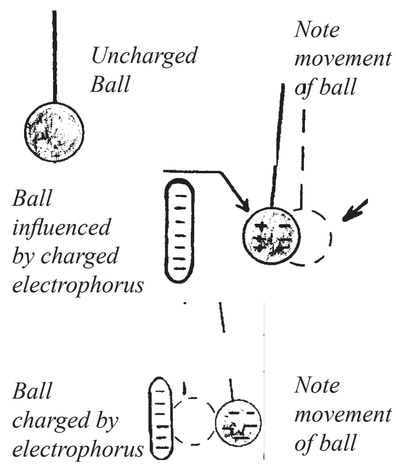


Figure 6

Discussion:

This demonstrates several electrostatic properties. Attraction takes place between opposite charges and repulsion between like charges, as in *Procedure 1*. The forces of attraction/repulsion come from the electric field surrounding charges (*Fig. 7.*)

If an isolated electron is in the field, it would move towards the positive pole (charge concentration) and away from the negative pole.

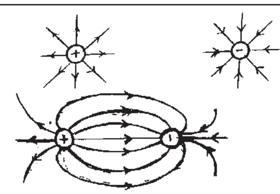


Figure 7

The experiments in *Procedures 2 and 3* demonstrate the concept of **electrostatic induction,** whereby a charged body induces an opposite charge in an uncharged body placed close to it. (Example - charged rod held close to uncharged pith ball.) Molecules of the pith ball reorient themselves such that their electrons are closest to the positive end of the charged body (*Fig. 8).* In doing so they acquire the opposite charge.

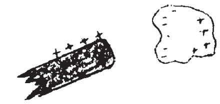


Figure 8

Subsequent to induction, there is attraction (between pith ball and rod) due to opposite polarity between them. When they touch, there is direct transfer of electrons by conduction. The two bodies face each other with like charges and therefore repel. The sequence induction, attraction, conduction and repulsion explains the bounding behavior of the pith ball in *Procedure 3.*

Advanced Concepts:

- Electrostatic attraction and replication of a DNA molecule; the passing on of genetic characteristics during cell division.
- Ionic vs chemical bonds.

Experiment 4:
Separating Mixtures Electrostatically

Additional Items Needed:

- Salt and pepper
- Paper

Kit Components Needed:

- Acrylic charge plate
- Acetate cloth

Procedure:

1. Spread mixture of salt and pepper (think of other combinations to use!) evenly on a sheet of paper lad flat.
2. Place plate above paper, supported on 2 blocks or books as in *Fig. 9.*
3. Give a negative charge to the plate by rubbing its top with acetate cloth.
4. Watch pepper particles jump to the bottom of the plate (by induction and attraction), fall down (due to contact, conduction and repulsion) and bounce up again.

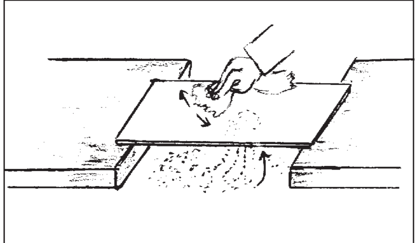


Figure 9

5. Cut out a paper piece in some shape (the number "8", for example) and tape to the surface of the acrylic plate. Since the plate does not get charged in the parts covered by the paper figure, the pepper is finally attracted and held to the parts covered by the figure.

Discussion:

This illustrates the principle of the photocopier machine, where toner dust is attracted to the surface of a sheet of paper by electrostatic attraction and fixed by heating. Other examples include: the filtering in air pollution devices; the illumination of TV monitor screens.

Experiment 5:
Storing and Transferring Electrostatic Charges - Electrophorus and Proof Plane

Kit Components Needed:

- Electrophorus
- Acrylic plate
- Neon lamp (optional)

Procedure:

Charge an electrophorus as in Fig 9.

1. Rub plate with polyethylene so plate acquires negative charge. Place flat on table.

2. Holding electrophorus by handle, bring disc close to acrylic plate. By induction, the top acquires negative charge (electrons reorient and are driven to the top).

3. Touch the top with a finger to discharge as electrons flow through your body.

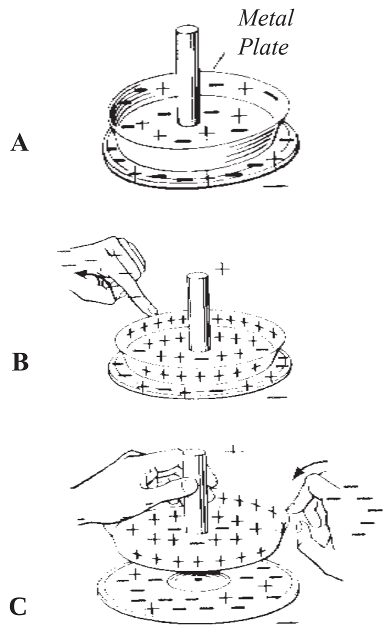


Figure 9 - An Electrophorus. A) A metal plate lying on a negatively charged surface. Electrons are repelled to the upper surface of the plate. B) When you touch the plate, the electrons escape from it. C) Lift the positively charged plate. Bring your finger near it. You will get a spark.

Note: *You can show the discharge by using the neon bulb. Hold one lead with your finger and touch the disc top with the other lead; the bulb will glow to show there is a charge flowing.*

4. Remove your finger. The disc has a net positive charge (fewer electrons.)

5. Pull away disc from plate, holding it by handle.

The electrophorus is positively charged.

Note: *You can place the disc on the charged insulator plate in Steps 2, 3 and 4. Contact is only at a few microscopic projections to which the insulator does not conduct electrons.*

Electrons on the insulator leak away.

6. Transfer charges for different purposes from the "reservoir" of positive charges built up in the electrophorus.

Use a proof plane or transfer ball to charge an electroscope

(See *Figure 10.*)

Note: *An electroscope detects and identifies electrical charges. Presence of charge makes its vanes diverge (due to similar charges acquired by both). In the absence of charge, the vanes remain neutral and collapse.*

To charge an electroscope:

- Touch proof plane ball to disc. It acquires a positive charge by contact (conduction.)
- Move proof plane to electroscope and touch ball to terminal.
- Vanes diverge due to the deposit of positive charge.
- You have used the proof plane to transfer positive charges. Can it transport negative charges?
- Discharge proof plane by grounding it. Repeat with negative charges. At first, the vanes collapse. Bring more charges, they diverge. Why?

Discussion:

Figures 10 and *11* show the charging of the electroscope with both positive and negative charges done by conduction. The initial collapse of vanes is due to neutralization of vanes by the negative charges you are depositing. The subsequent deposit of negative charges will make the vanes diverge because like charges were acquired.

The proof plane in the experiment is physically transporting electrostatic charges or static electricity.

Static vs current electricity An electric current (or flow of electrons) along a conductor can be generated by a perpendicularly moving magnetic field. Think of current electricity as the flowing water of a river, the generators as the water pumps and the wires as the water pipes. By contrast, static electricity (that is, stationary charges) is like water in a lake. Provide a channel and electrostatic charges can also flow and become current electricity.

Static electricity can be generated using mechanical means. Electrostatic charges can be carried and moved as electrons adhere to matter and go with them. While an electric current can be likened to the flow of liquids from a higher to a lower level, moving charges is like transporting liquids with dipper and pail.

Experiment 6:
Charge an Electroscope by Induction.

Kit Components Needed:
- Electroscope with assembly and flask
- Friction rod

Introduction:
An electroscope detects the presence of an electrostatic charge by being "charged" by it.

Try charging the electroscope, first with a positive charge and then with a negative charge, as follows.

Procedure:
1. Fit one of the electroscopes with a ball terminal assembly.

2. **Charge a glass rod positively** by rubbing it with silk and bring the charged (rubbed) end close to, but not in contact with, the ball terminal of the electroscope.

3. Observe the leaves of the electroscope diverge (go apart).

4. Remove the charged rod away from the electroscope terminal and observe the electroscope leaves collapse.

5. Repeat the entire procedure above, and observe the leaves repeat their behavior, diverging and collapsing just the way they did before.

6. Repeat the entire procedure, using an uncharged glass (or other) rod. Observe that the leaves do not diverge.

7. Instead of the positively charged (glass) rod, use a negatively charged rod (rub acrylic with wool or flannel) and repeat the experiment. Observe that the leaves behave exactly as they did before for a positively charged rod.

8. Try a variation now. Bring a positively charge rod close to the electroscope terminal, and with it still there, touch the terminal with your finger. Then remove the rod. Notice that the diverged leaves continue to remain so, instead of collapsing as they did in step 4 and 5.

CONCLUSION: Any charged body (either positive or negative) brought close to, even though not in contact with, an electroscope terminal, makes the leaves diverge. And they collapse when the charged body is taken away.

6. Induction is actually a consequence of the forces of attraction and repulsion between charges in an electrostatic "field".

CONCLUSION: In this part of the experiment, the leaves not only acquire the charge, but they retain it. The electroscope is "charged."

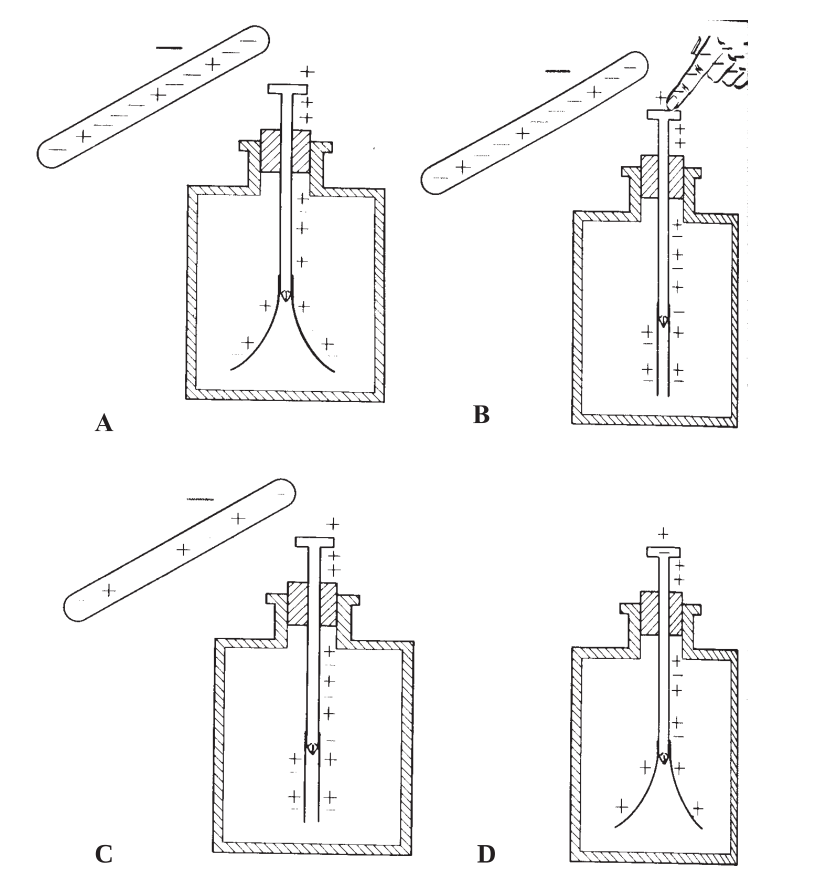


Figure 10 - Charging the Electroscope by Induction. (A) The negative rod repels electrons to the leaves. (B) When the electroscope is grounded, electrons are repelled to the earth. (C) The ground is removed first, then the rod. (D) The electroscope, having lost electrons, is charged positively. The rod lost no charge.

Discussion:
1. The above experiment is a case of charging the electroscope by *"electrostatic induction",* where a charged body (the rod) *"induces"* an opposite charge in an uncharged body (the electroscope terminal and the leaves, which are really an extension of the terminal, being connected to it through electrically conductive parts). This happens due to the reorientation of molecules in the uncharged body so their electrons will be closest to the positive end of the charged body. In other words, more electrons are drawn toward the terminal, causing the leaves to have less of them; or, electrons are driven to the leaves from the terminal, as the case may be. The leaves thus acquire the same charge as the rod, and the terminal the opposite charge, by induction.

2. Why the divergence of leaves? Both leaves acquire a similar charge by induction, positive or negative, with the result that they repel each other.3. What makes the leaves collapse? In induction, there is no contact between bodies, no actual transfer of electrons, only a temporary rearrangement of them by the reorienting molecules. Once the "charge inducing" rod is removed from the scene of action, the molecules return to their normal state, with the result that the leaves no longer carry the charge, and they collapse (no need to repel each other).

4. Why do the leaves retain the acquired charge in the last Experiment, but not earlier? It is because you have "grounded" the induced charge on the terminal (removed excess electrons from it) by touching it with your finger; whereas, the leaves continue with the positive charge they acquired.

5. You can use an electroscope to verify the presence or absence of an electrostatic charge on a body. A diverging electroscope would indicate, in these experiments, the presence of a charge on the rod; and a non-diverging electroscope (with collapsed leaves) would mean that the rod had no charge on it.

Experiment 7:
Charge an Electroscope by Contact

Kit Components Needed:
- Electroscope with ball or disc terminal
- Friction rod

Introduction:
You can charge an electroscope by **conduction** rather than by **induction** (unlike the previous experiment) by having the charged body in direct contact with the terminal. Use it as follows.

1. As before, set up the electroscope with the ball terminal assembly (or, for variety, the disc terminal assembly).

2. Bring a positively charged rod close and see the leaves diverge.

3. Now actually touch the terminal with the charged end of rod and note that the leaves remain diverged.

4. Remove the rod and observe that the leaves still remain diverged.

5. Repeat, this time using a negatively charged rod instead of positive, making sure to discharge the electroscope first. Note that the leaves behave the same, and remain diverged.

Discussion:
1. This is a case of *charging by conduction.* When the charged rod is brought close to the terminal, it induces an opposite charge in the terminal by induction, while the leaves acquire the same charge as the rod. But then when the rod touches the terminal it establishes a continuous conducting channel for the flow of the electrons into it, so the electroscope assembly now stays with a net negative charge.

2. Whereas induction is a case of mere reorientation of molecules (that is to say, a temporary repositioning of electrons) within the uncharged body, during conduction there is actual transfer of electrons to fill in the deficiency.

3. Compare the act of "touching" to the action of the finger previously.

Experiment 8:
Use an Electrophorus or a Proof Plane to charge an Electroscope.

Kit Components Needed:
- Electrophorus
- Friction Rods
- Proof Plane

Procedure:
1. Impart a positive charge to an electrophorus by placing it above a negatively charged (acrylic rubbed with acetate cloth) plate; draining off excess electrons from its top by grounding; and lifting it off the plate along with the net positive charge it has acquired.

2. Perform the Experiments 1 and 2 and charge the Electroscope using the Electrophorus instead of the (positively) charged rod.

3. You can charge the electroscope by transferring charges a bit at a time from the Electrophorus, using a Proof Plane. This method of charging an electroscope is convenient, as you will see later, when you have to repeatedly charge it for identification of an unknown charge, that is, to find out which kind of charge (+ or -) a body is carrying.

Experiment 9:
Determine an unknown charge with a known charged body and an electroscope.

Kit Components Needed:
- Electroscope- ball or disc terminal
- Friction Rods

Procedure:
1. Set up the electroscope, either with a ball terminal or a disc terminal.

2. Charge it positively by any of the following methods:

Method 1:
Hold a negatively charged rod (acrylic rubbed with acetate cloth) close to the terminal. Touch the terminal with your finger. This repels and drains off electrons from the electroscope into your body, and leaves it with a net positive charge.

Method 2:
Directly transfer charges from a reservoir of positive charges, such as a charged electrophorus, on to the electroscope terminal and charge kit by conduction.

3. Since you know what kind of charge the electroscope has (positive charge in this case), you can easily identify the sign of an unknown charge brought to its terminal.

Bring the charged body in test close to the terminal. Observe whether the vanes (which are already diverged) will diverge even more or just collapsed.

In the first case you can conclude that the body is positively charged, whereas in the second case, it is a negatively charged body.

Discussion:

1. The positively charged vanes of the electroscope diverge even more by any positive charge(s) placed at its terminal, because it causes electrons to be attracted and driven up into the terminal from the leaves.

2. Conversely, any negative charge(s) placed at the terminal of the electroscope neutralize the already present positive charges on the vanes by driving electrons down into them.

Experiment 10:
Charge two electroscopes simultaneously by induction.

Kit Components Needed:

- Two electroscopes (with disc terminals)
- Charged Rod or Electrophorus

Procedure:

1. Set up both the electroscopes provided in the kit with disc terminals and arrange them side by side with terminals touching.

*[**Note:** for best results, place electroscopes on a metal table top or piece of aluminum foil. Make sure that they are completely discharged]*

2. Bring a charged body (rod or electrophorus) near both electroscopes.

*[**Caution:** Take care not to touch the terminals while handling; also, not to charge the electroscopes too much, beyond a 45 ° deflection of leaves.]*

3. Watch vanes diverge in both electroscopes, showing a charge in each.

4. Move the electroscopes apart.

5. Remove the charged body; and note that both vanes remain diverged.

The electroscopes have been charged.

6. You can test for the sign of the charge on each of them by bringing them together again so terminals touch.

Observe that the leaves collapse.

*[**Caution:** For best results, you might have to try repeatedly. Consider the possibility that accidental transfer of charge might have occurred by holding the charged body too close to the electroscope, as also leakage from it by accidental handling.]*

7. You can conclude that the electroscopes acquired equal and opposite charges by induction.

Discussion:

The presence of the charged electrophorus induces a negative charge at the near end of the electroscope pair - the terminals and vanes of the first electroscope thus acquiring a negative charge. The other electroscope acquires a positive charge, being at the far end.

When the electroscopes are separated, the first electroscope is left with a net negative charge, whereas the other electroscope has a positive charge. And they retain the charge even after the source of charging is removed. Thus they have been oppositely charged.

Further, since electrons were neither added to nor taken away from the electroscopes, the charges they acquired must be equal.

Since equal and opposite charges total to zero, it explains why the vanes collapse as the terminals touch again, when the electrons get redistributed.

CONCLUSION: The electroscope gets charged when its terminal comes into contact with a (positively or negatively) charged body.

Experiment 11:
The Electric Field Inside a Conductor is Zero: Faraday Cage Experiment

Kit Components Needed:

- Electroscope with ball terminal
- Faraday Cage on stand
- Electrophorus
- Second electroscope with ball or disc terminal

Procedure:

1. Set up an electroscope with its foil leaf assembly. *Fig 11*

2. Make sure the Faraday Cage is on its metal base, mount base on insulated stand (caplug.) Place the electroscope carefully within the cage; cover it.

3. Charge an electrophorus. *[Hint: Review the experiment on electrophorus in prior experiment.]*

4. Bring electrophorus in contact with outside of the cage at various points either directly or by means of a transfer ball. *(See prior experiment.)* If there is really no charge inside a conductor, it shouldn't be possible to charge this electroscope by applying a charge to the conductor surrounding it. Several contacts with a charge electrophorus can build up a potential of 1,000 volts or so on the cage. Yet, there is no noticeable effect on the electroscope inside. What very slight effect there is, is due to the many holes in the conductor. A completely enclosed electroscope would show absolutely NO deflection.

5. Notice the electroscope shows no deflection.

6. Set up another electroscope (either with a disc or ball terminal) and bring it close to the cage on the outside.

7. Observe the deflection (and the intensity of it) in its vanes.

CONCLUSION: The cage has acquired a charge and all of the charge is on its outside! There is no electric field (because of no charge) inside it, in spite of the high potential buildup on its outer surface.

*[**Note:** If you placed a positive charge within the cage, the electrons would be forced to be on the inner surface this time so the outer surface is positively charged. You can verify this by introducing a positively charged proof plane into the Faraday Cage.]*

Discussion:

1. Why did the cage not acquire any charge inside it - in its hollow part? It is because the cage is made of metal and metals are good conductors. When charges are at rest, the electric field inside a good conductor is always zero, and any net charge on it distributes itself on the outer surface.

This is because a good conductor has free electrons and any force they would experience due to an electric field would drive them to positions until the net force on them would become zero.

In the case of a negatively charged cage, for example, if there did exist an electric field within it, the electrons would flee from the center all the way to its surface in order to get away from one another as far as possible. This leaves no net charge on the inside of the cage.

Experiment 12:
Faraday's Ice Pail Experiment

Kit Components Needed:

- Electroscope with disc terminal
- Ice Pail
- Proof planes

1. Set up an electroscope with disc terminal; make sure it is discharged.

Fig. 11

2. Place the Faraday's Pail (aluminum tumbler) on top of the disc terminal.

3. Charge an electrophorus and reserve it at a distance (where it will not affect the electroscope). *Fig* 12 A.

4. Charge a proof plane transfer ball by touching it to the electrophorus, and then lower it into the Faraday Pail carefully without touching its sides.

5. Observe the deflection of the electroscope vanes. *Fig 12 B.*

6. Withdraw ball; vanes collapse.

7. Reinsert charged ball. Rotate it within the pail without touching its sides. Watch vanes diverge to the same extent for every direction the ball moves.

8. Touch the ball to the inside of the pail; note that the deflection of the vanes remains unchanged.

9. Remove the transfer ball. Discharge it and use it to remove any charge from the outside of the pail (by touching it to the outside) and test it. Use second electroscope for testing.

10. Repeat step 9, this time trying to remove any charge from the inside of the pail. Note that the test identifies no charge on the transfer ball.

CONCLUSION: Whatever charge was on the pail was not inside of it.

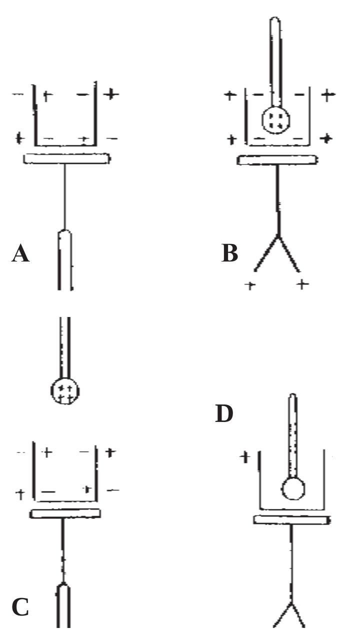


Fig. 12. A. Ice pail on disc terminal of one electroscope. Charge electrophorus and remove.
B. Lower ball into can without touching can. Note electroscope deflection.
C. Remove ball, note deflection.
D. Reinsert charged ball and move it around without touching pail. Note equality of electroscope deflection.

Discussion:

1. Why the deflection in the electroscope when the transfer ball is lowered into the pail? It is because the positive charge it carries draws electricity.

2. Withdrawal of the ball restores the electrostatic equilibrium in the pail and in the vanes, since there was no actual transfer of electrons, but only a temporary reorientation of them.

3. When the charged ball is reinserted, it causes the vanes to diverge as before; however, touching the (negatively charged) inside of the pail with it will attract and remove the excess electrons from the inside and leave it neutral (discharged.)

4. So far the purpose of the experiment was to demonstrate how to charge just the outside of a metal pail by induction without affecting its inside.

The rest of the experiment verifies this. Discharged ball touching the outside of the pail gets some of its positive charge; and when it is taken to the second electroscope (which is previously positively charged) for charge identification, its vanes go further apart; this indicates additional positive charges coming (by induction) from the ball, which confirms the presence of positive charge on the outside of the pail.

On the other hand, the discharged ball picks up no charge from the inside of the pail and therefore not having any effect on the vanes of the test electroscope (previously charged as before); they neither diverge more nor collapse, indicating the total absence of charge on the ball, and therefore in the inside of the pail. *(Review Experiment 3)*

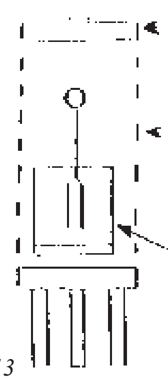


Figure 13

Experiment 13:
Surface Distribution of a Charge

Kit Components Needed:
- Faraday Cage
- Electroscope

Introduction:
Electrons repel each other. They get as far from their neighbors as possible.

A projection from a body presents a special case. Those electrons out on the projection experience more force away from the others. See *Figures 19 and 20.* **Note:** the electron on the projection receives a force pushing it off the projection.

Electrons tend to be pushed off projections and sharp corners. If this is so, the transfer ball will gather larger charges at sharp corners than at flat surfaces.

1. Use Faraday's Cage as set up in *Figure 13.*
2. Gather charges from sides, center and corners of Faraday Cage .
3. Compare the electroscope deflecion for each.
4. Discharge the electroscope between tests.

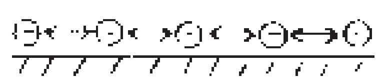
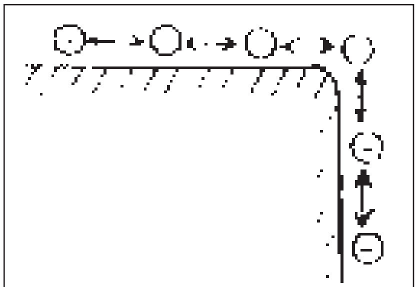


Fig. 14


Note the direction of the forces acting on this electron

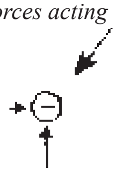



Fig. 15.

Experiment 14:
Discharge from a Point

Kit Components Needed:
- Electrophorus
- Faraday Cage
- Electroscope
- Mounted Point

Procedure:
1. Charge electrophorus and place it on the insulating stand from the Faraday Cage (*Figure 16, B*).
2. Place an electroscope near enough to show a deflection. The electro scope indicates an electrically charged object nearby (electrophorus). If the charge were removed from the electrophorus, the electroscope show it.
3. Attach a sharp point to the charged electrophorus (touch edge of electrophorus with a point on insulating handle (*Fig. 16, C*)
- *The charge has gone off the point into the air.*
4. If the point is aimed at an electroscope, some of the charge would go to it. (The electrophorus can be recharged.)

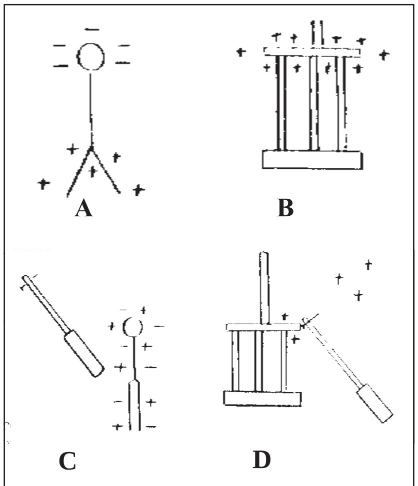


Figure. 16.- A. Uncharged electroscope
B. Electrophorus on caplug base from Faraday Cage
C. Mounted point.
D. Charge escaping to surroundings.

Common Materials as Charge Generators:

Excellent at All Humidities:
Sulfur
Polystyrene
Polyethylene
Paraffin wax
Pure gum rubber
Vinyl plastic

Excellent at Low Humidities, Unreliable at High Humidities:
Porcelain
Glass
Mica
Acrylic plastic
Epoxy plastic
Polyester resin
Shellac
Beeswax

Unreliable at Moderate Humidities:
Wood products
Paper products
Hard rubber
Phenolic resins
Synthetic fiber
Fur
Cloth - all kinds
Soft glass
Rubber*

**Some rubber and plastic products have been treated to make them slightly conducting.*

References:

1. Blackwood, O.H., Herron, W.B. and Kelly, W.C. High School Physics. Boston: Ginn & Company, 1961. (pp.400-423)
2. Cunningham, J. and Herr, N Hands-on Physics Activities. West Nyack, N.Y: Center for Applied Research in Education, 1 994. (pp.538-563).
3. Giancoli, D.C. Physics: Principles with Applications. (3rd.Ed.) Englewood Cliffs, N.J: Prentice-Hall, 1991 (pp 416-458).
4. Thurber, W.A. and Kilburn R.E. Exploring Physical Science. Boston: Allyn and Bacon, Inc. 1970 (pp 337-368).

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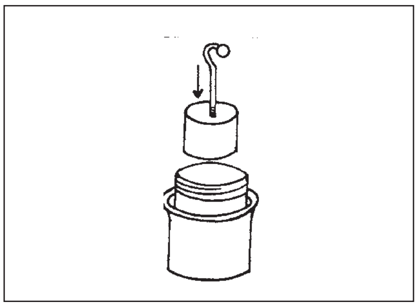
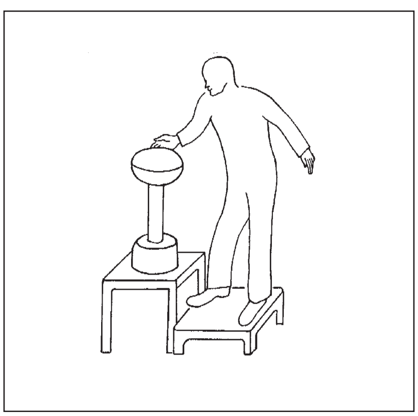
615-3205 Leyden Jar - Charge it, dissect it - holds a charge for hours. A good teacher demonstration for proving that a charge is stored in the insulator, not in metal surfaces. Instructions.

10- 060 Van de Graaff Generator - A fun source of static electricity



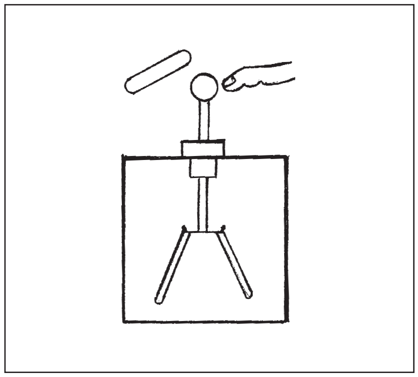
with potential of 200,000 volts! Completely safe - no chock hazard. Works in humidities up to 90%. Raise hair instantly - create sparks up to 6" long. With spare neoprene belt, 12-page instruction booklet. Also available in museum size -

615-3130 Large Van de Graaff with 400,000 volt potential.

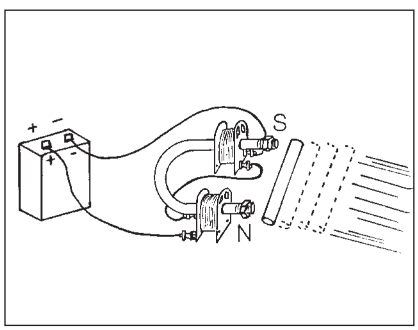


615-3015 Friction Rod Kit - New! Make electricity the way the ancients did. Includes glass, acrylic, hard rubber rods; cotton, fur and acetate pads. Instructions.

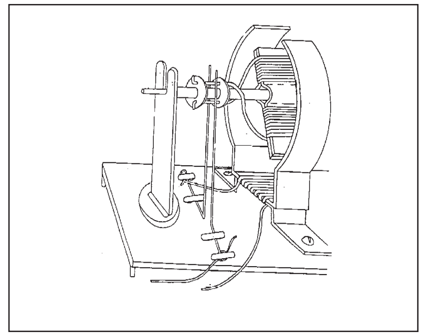
615-3078 Electroscope - Show how two similarly charged objects repel. Classic device with 10 x 10 cm square viewing area. 2 pie cur-cut foil leaves, brass hanger, 2 glass plates, ball terminal, insulator, instructions.



611-2261 Electromagnet Kit (Gilley Coil) - Everything you need to build a powerful electromagnet. Experiment with induced currents, reversed polarity, magnetic lines of force. Includes 2 coils with binding posts; round, square iron cores; 2 half-round cores; double U core; 4 clip leads; iron filings; instructions with labs. Good for science fairs. *You need 6 v lab power supply.*



615-0300 Lifting Magnet - Weighs 2 pounds, lifts 200 due to precision machining. Functions the way magnets lift cards in junkyards. Instructions, alligator clip leads and battery holder. *Bigger and better - **20-035** weighs 5 pounds and lifts up to 700!*



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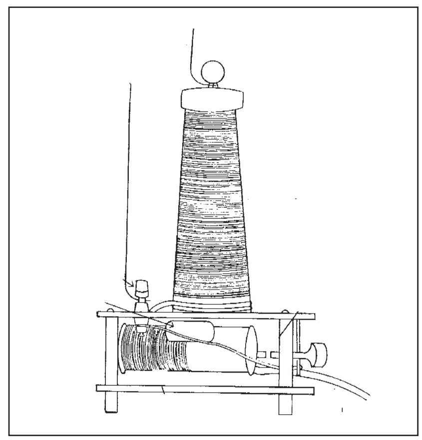

615-4665 Tesla Coil - Transmit electricity without wires. Watch light bulbs glow in your hand. Hard-to-find source of high frequency high voltage electricity. Completely safe as electricity flows harmlessly over your skin. Arcs to 2", 50,000 volt potential. Complete accessories. Instructions with 19 experiments.

How To Teach With Electrostatic Kit:

Concepts Taught: Electrostatic attraction/repulsion; electrostatic conduction and induction. Charge distribution on a surface; field inside a conductor; charge generation; charge conservation; charge transfer. Charging/discharging. Lightning rod.

Curriculum Fit: PS/Electricity and Magnetism; *Unit: Static charge. Grades* **4 - 12.**