Naive Ideas about Electricity

From Operation Physics "Electricity"
The American Institute of Physics

The following is a list of naive ideas that students might be expected to have concerning electricity. Our goal is to help them change their naïve ideas to those most supported by scientific research.

1. After a material acquires a positive charge, it has more positive charges (protons) than it did before.
2. After a material acquires a positive charge, the missing negative charges (electrons) have been destroyed and no longer exist
3. Whenever a material becomes charged, the charges have been newly created in the process
4. Atoms are charged. (Positively-charged atoms give materials a positive charge; negatively-charged atoms give materials a negative charge.
5. Static electric forces are always attractive.
6. In order for an object to act like it is charged, electrons must be added or removed
7. Gravitational forces are stronger than electric forces.
8. Wires must be coated with an insulating material or the electric energy will leak out. All wires are insulated.
9. Electrical energy flows from source to converter (light bulb, heater, appliance, etc.) by connecting a single wire.
10. If two wires are needed, energy flows from the source to the converter (light bulb, heater, appliance, etc.) through both wires.
11. In a circuit with electrical devices, more electrons leave the source than return to it.
12. Electrons are destroyed or "used by" the converter (light bulb, heater, appliance, etc.).
13. The electrons that comprise an electric current move very fast at or near the speed of light.
14. The electrons that comprise an electric current come from the source. (A dry cell is a can full of electrons. When it is out of electrons, we throw it away or recharge it.)
15. Every part of a circuit gets the same current.
16. As many converters (light bulbs, heaters, appliances, etc.) as you wish can be connected in a circuit without affecting their behavior (brightness, etc.).
17. To receive more light from a bulb, you need a different light bulb.
18. Placing more batteries in a circuit always increases the current (makes a lamp brighter, a motor faster, etc.).
19. All materials that conduct electricity conduct equally well.
20. Water is a good conductor.

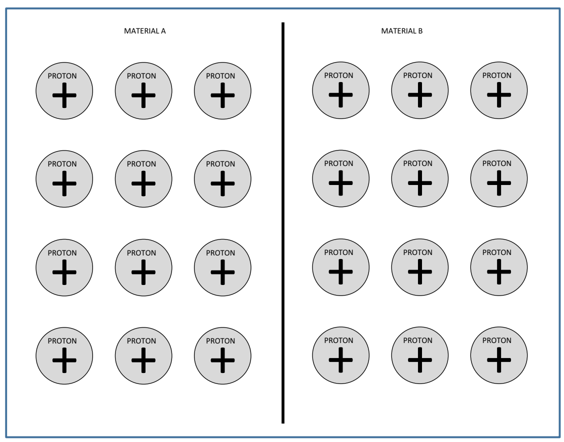
HOW DO MATERIALS BECOME CHARGED?

Materials:

- Printed “Proton Page”
- Counters or tokens

1. Print the electron and proton pages.
2. Cut out the 25 quarter-sized “electrons” on the electron page. You can also use some type of tokens to represent electrons. These can be anything that will fit on the “protons” on the proton page.

Proton Page



Electron Tokens

3. Place one electron on each of the ten protons from Material A. Remember, +1 and -1 combined equals zero. What is the “net” charge on Material A? (“Net” charge is the remaining charge after all the +1 charges and -1 charges have been combined.)

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4. Place one electron on each of the twelve protons from Material B. What is the net charge on Material B?

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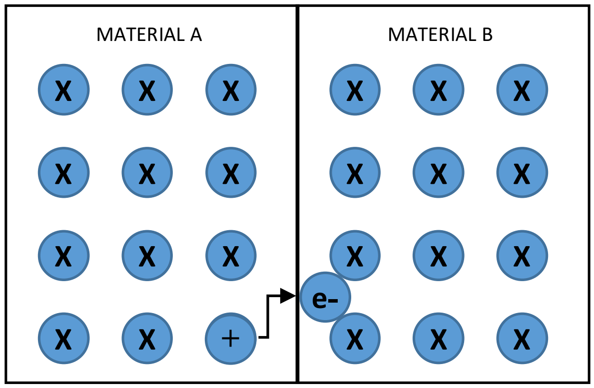
5. One way of moving electrons from one material to another is by contact (rubbing the materials together increases the number of contacts). Pretend that Material A and Material B are gently rubbed together. Move one electron from Material A to Material B.



X = Electron Proton Pair
+ = Proton
- = Electron

6. What is the "net" charge on Material B?

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7. What is the "net" charge on Material A?

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8. Move the extra electron back to Material A.

9. How many electrons must be added to give Material B a "net" charge of -3?

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10. How can you give Material A a net charge of +4?

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11. Which part of an atom can be moved to charge a material? EXPLAIN.

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12. If one material gains electrons to acquire a "net" negative charge, what must also be true of the other material?

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What you have just discovered is that no electrons are created or destroyed but are simply transferred from one material to another. This is called the Principle of Conservation of Charge. (that is, if one material gains electrons, another must lose those same electrons).

HOW DO MATERIALS BECOME CHARGED?

IDEA:
A positive charge forms when electrons are removed from a material. A negative charge forms when electrons are added to a material.

PROCESS SKILLS:
Observing
Communicating

LEVEL: U/L

DURATION: 15 Min.

STUDENT BACKGROUND:
Addition of positive and negative numbers is a helpful skill for upper level students. However, lower level students can accomplish the same thing by pairing protons and electrons to “cancel” the charges. The charge on one proton (+1) and one electron (-1) neutralize each other (positive one plus negative one equals zero). When all proton-electron pairs have been formed, the remaining positive or negative charges can simply be counted.

Students should know that all matter contains atoms and that atoms are composed of protons and electrons (also neutrons, which aren’t considered here). Protons have a +1 charge and are fixed structures found in the nucleus. Electrons, although they are smaller in mass than protons, carry a -1 charge. Electrons orbit about the nucleus of an atom. The outermost electrons of some materials are loosely held and are able to be pulled away from one atom and transferred to another. The positive charge on a proton is exactly equal in strength but opposite in sign to the negative charge on an electron. The charge on one proton and one electron, when combined, is equal to zero.

ADVANCE PREPARATION:
Print the proton page and the electron page (if you are not using tokens for electrons). If you are using the printed electrons you may precut them or allow the students to cut them out. This will take a while depending on the age of the students.

MANAGEMENT TIPS:
Use a transparency, document camera or model boards and tokens you have prepared to physically put one proton and electron together to form a neutral pair. You may want students to pair electrons with protons on their boards by placing the electron face down on the proton. This will leave a blank side facing up that will say to the student, “ignore, these two cancel each other.” After all pairs have been made, the net charge can be determined by simply counting the unpaired protons or electrons.

For example, if 3 protons are left unpaired, the net charge would be +3. If 2 electrons are left unpaired, the net charge would be -2. Obviously, protons and electrons cannot both be left over at the same time because they would form additional neutral pairs. It would speed up the procedure to precut the tokens.

RESPONSES TO SOME QUESTIONS:(from pages #2 and #3)

3. Zero.
4. Zero.
6. -1
7. +1
9. 3 electrons.
10. Remove 4 electrons.
11. Only electrons can leave an atom and move to another material.
12. It must lose the same number of electrons.

POINTS TO EMPHASIZE IN THE SUMMARY DISCUSSION:

One main point to emphasize is that protons cannot move between atoms, but electrons can. Positive and negative "net" charges both result from the movement of electrons. Students may have the same freedom of movement as electrons.

Another point of emphasis is "conservation of charge." When one material acquires a net negative charge by gaining electrons, another material must acquire a positive charge from the loss of those same electrons. Electrons cannot just appear out of thin air, nor can they be lost. Electrons simply shift from one material to another.

A third point to emphasize is that the net charges formed when electrons are removed or added to a material are called static charges if the charge remains in one location. The word "static" need not be brought up until the end of the lesson. The opposite of static charges are charges that move. Charges (electrons) that move through a material from one location to another are called current.

POSSIBLE EXTENSIONS:

Students should be provided with a lot of practice in determining net charge. The Proton sheets and tokens can be used to solve problems made up by the teacher. For lower level students, excess or net charge can be modeled by pairing the boys with girls in the room. Any leftover (unpaired) boy or girl would represent the "net" number of children of a given gender in the class. For upper level students, earnings and expenses can be used to determine "net" profit or loss.

Some of the materials on the previous 5 pages is part of the Operation Physics Manual: Electricity. It is used by permission and has been reformatted and modified.

MATERIAL A

PROTON PROTON PROTON PROTON

PROTON PROTON PROTON PROTON

PROTON PROTON PROTON PROTON

MATERIAL B

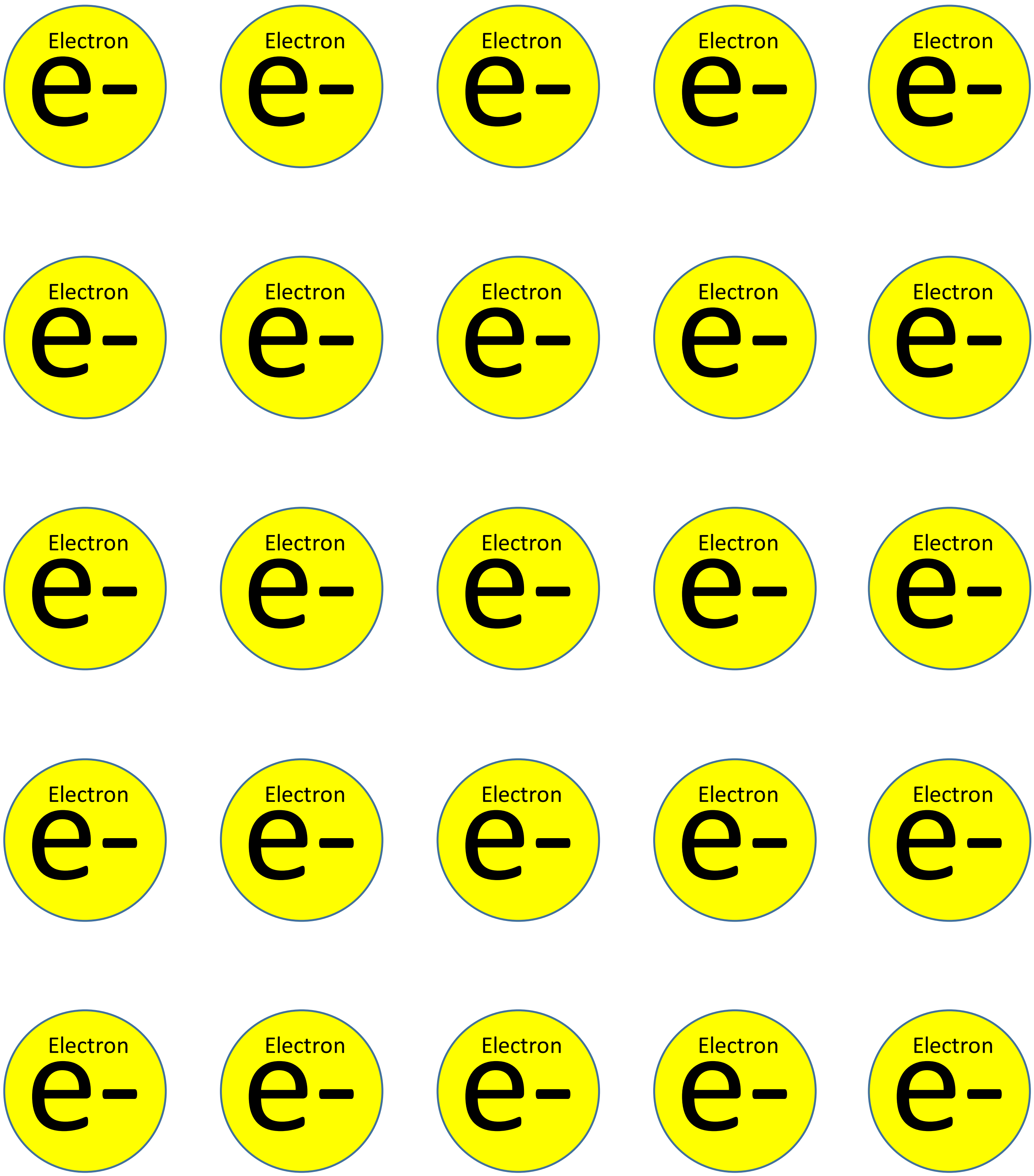
PROTON PROTON PROTON PROTON

PROTON PROTON PROTON PROTON

PROTON PROTON PROTON PROTON

ELECTRON TOKEN TEMPLATE

(To be cut out)



FOCUS ON PHYSICS
STATIC CHARGES
(Discussion)

The building blocks of matter, atoms are composed of particles possessing a unique, fundamental physical property called electric charge. The electron, by definition, has a negative electric charge and the proton has a positive electric charge of exactly the same size. The third particle in the atom, the neutron, has zero electric charge, or is said to be electrically neutral.

The protons and neutrons of the atom are tightly packed into the center of the atom, called the nucleus. Electrons revolve around the nucleus of the atom. The outermost electrons of some atoms are loosely held and can be transferred to other materials. This transfer of electrons causes materials to become charged. When electrons are lost, the material has more protons (positive charges) than electrons (negative charges) and becomes positively charged. A material that gains electrons becomes negatively charged because it has more negative charges than positive charges.

There are three possible charge states for a material:

Neutral - The number of positive and negative charges are the same so the net charge of the material is 0.

Negative Charge - The material has more negative charges than positive charges so the net charge is negative. This happens when a material picks up electrons from another material.

Positive Charge - The material has more positive charges than negative charges so the net charge is positive. This happens when a material loses electrons to another material.

The unit to measure the quantity of electric charge is the coulomb. The size of the coulomb is such that macroscopic amounts of charge can be measured easily in the laboratory. In fact, the charge carried by an electron is only 1.6×10^{-19} coulomb or 0.00000000000000000016 coulomb.

Electrons are not created or destroyed when materials become charged. They are simply transferred from one material to another. Therefore, we say that charge is conserved.

Many materials will exchange electrons when in contact. These materials will exchange electrons whenever they come in contact with one another. The numbers of electrons transferred is a function of the atomic structure of the two materials. Rubbing the materials together DOES NOT rub electrons off one material to another. The rubbing simply maximizes the contact between the two materials and therefore maximizes the electron exchange. In fact, aggressive rubbing may create heat from friction which can impede electron transfer.

With the knowledge that some atoms either loose or gain electrons to become charged, we have been able to make lists of materials that will receive or lose electrons. Such a list is called an "electrostatic series" or "Triboelectric Series." An "electrostatic series" lists common materials in the order of their tendency to receive or lose electrons. The electrostatic series on the following page is arranged such that materials which tend to give up electrons and become positively charged are at the top of the list. Those that have a tendency to gain electrons and become negatively charged are found at the bottom of the list. Any material on the list gives up electrons to a material above it. The further apart the materials are on the list, the more easily electrons are transferred from one to the other.

Using the list on the next page, we can choose two materials widely separated on the list and produce a static charge by bringing these two materials together. Also, we can understand which material loses electrons and which material gains electrons.

The word "static" comes from the Greek word meaning "standing" or "stationary". The term "static electricity" is used to describe the electrical properties of charges at rest. Electric current refers to the movement of charges through a conducting material

Electrostatic Series
(Triboelectric Series)

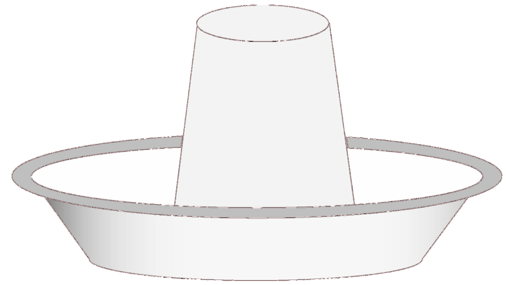
Loses Electrons (+)

Asbestos
Rabbit Fur
Glass
Mica
Human Hair
Nylon
Wool
Fur
Lead
Silk
Aluminum
Paper
Cotton
Steel
Wood
Amber
Sealing Wax
Hard Rubber
MYLAR®
Nickel
Copper
Silver
UV Resist
Brass,
Stainless Steel
Gold,
Platinum
Sulfur
Acetate
Rayon
Celluloid
Polyester
Styrene
Styrofoam®
Orlon®
Acrylic
SARAN®
Polyurethane
Polyethylene
Polypropylene
Polyvinyl Chloride (PVC)
Vinyl
KELF
Silicon
Teflon
Silicone
Rubber

Gains Electrons (-)

Electrophorus

Construction and Use

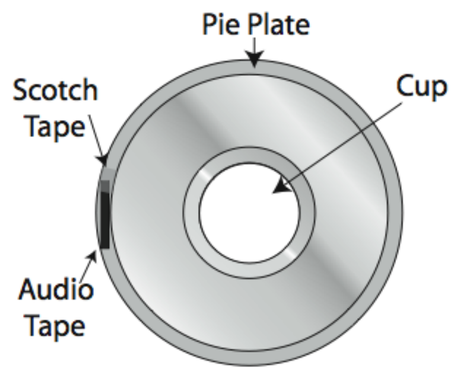


Materials:

- Aluminum Pie Plate
- Styrofoam® (plate or 10”X10”X1/2” square)
- 100% Wool Cloth
- Magnetic Audio Tape
- Scotch Tape
- Styrofoam® Cup
- Electrostatic Series (Triboelectric Series)

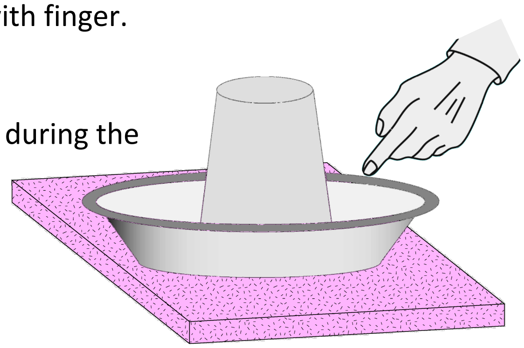
Procedure:

1. Tape Plate to table (Optional)
2. Tape top of cup to inside of pie plate as in diagram.
3. Tape small piece of magnetic audiotape to lip of pie plate so that the tape lies along the lip of plate.
4. Rub Styrofoam® gently with wool.
5. Check for Static charge by holding back of your hand over the Styrofoam® and feel if the hairs move.
6. Place pie plate on Styrofoam® using cup as handle.
7. Slowly bring finger to edge of pie plate.
8. Observe magnet tape.
9. Lift pie plate at least 25 cm by cup and slowly touch with finger.
10. Observe Magnetic tape.



Discussion:

With your partner discuss the movement of electrons during the above procedures. Journal your discussions below.



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Electrophorus
Teacher notes

In order to determine the level of student comprehension, each student needs to model the movement of electrons during the process of charging and discharging the Electrophorus. Their response should be similar to the following.

1. According the Electrostatic Series, wool will lose electrons to Styrofoam when they come in contact. The Styrofoam will gain electrons and become negatively charged.

2. When I place the aluminum pie plate on the square of Styrofoam electrons will be repelled by the negative charge on the Styrofoam. Since it is a conductor they are free to move. They are repelled by the negative charge of the Styrofoam which pushes them as far away from Styrofoam as possible. This causes them to move to the top edge of the pie plate. I notice that the strip of magnetic audio tape stands up away from the pan. This indicates that the pie plate has a charge. Since it has not gained or lost electrons it has been charged by induction.

3. When I touch the pie plate with my finger (nose, cheek, etc.) electrons will move from the pie plate to me until the overall charge of the pie plate and the Styrofoam is neutral. The magnetic audio tape will lie flat.

4. When I pick up the pie plate, holding onto the Styrofoam cup, I notice that the magnetic audio tape stands up again indicating that the pie plate is charged. It is now charged because it lost electrons to me and now that it is no longer near the negatively charged Styrofoam it has a positive charge.

5. When I touch the pie plate nowP there is a small spark as electrons jump from my finger (nose, cheek, etc.) to the pie plate and the magnetic tape lies flat indicating that the pie plate now has a neutral charge.