

Elementary Science for Elementary Students

Demonstration: Electricity Made Simple

Core Concepts:	Voltage, Current
Other Concepts:	Elements in Parallel and in Series, Switches, Resistance, Diodes
Equipment:	Jigsaw Puzzle Rice and Comb (1), piece of wool Balloons (2), piece of wool Electricity Model (1) Electricity Protoboards (10) Resistors
Facilities:	Two grounded ac outlets

Introduction:

The core concepts in this demonstration are current and voltage. Electricity is a difficult concept for many people to grasp because these core concepts are not tangible or observable. Analogies between electricity and a more mechanical, observable phenomena are helpful to understand the flow and behavior of unseen electrons. Here, we refer to the flow of water through pipes as an appropriate analog to the fundamental concepts of electricity, current and voltage. Analogies, by definition, are limited however; the reader is forewarned that the flow of water does not completely equate to the flow of electrons or electricity. Behavioral analogies pointed out here, however, should be very useful for students of elementary and middle school age to grasp the unseen wonders of electricity.

This demonstration introduces the two major forms of electricity: static (non-moving) and dynamic (moving). Static electricity is the form of electricity familiar to many students in the form of electric shocks when touching metal in dry weather. Dynamic electricity, however, is the form of electricity needed to run any appliance: refrigerator, lights, computers, etc... It is dynamic electricity that we pay for in our monthly utility bills. Static electricity is free and often a nuisance: it can blow up (break) sensitive electronic components such as the microprocessors in our computers, microelectronic chips in our watches, and similar “semiconductor” circuits or devices.

This demonstration is divided into 3 major components as are all (ES)² demonstrations. Each component along with its major highlights is described below:

- **Pre-demonstration Exercise:** This exercise explores preconceptions about both static and dynamic electricity. Each student should complete the worksheet on page 8 of this document.
- **Interactive Lecture:** The lecture covers the core concepts and other concepts of the demonstration
 - Jigsaw puzzle, Rice and Comb, Balloons: Static Electricity
 - Large Electric Circuit Model: Dynamic Electricity
- **Experimentation Exercise:** allows groups of 2-3 students to experiment with a miniaturized circuit that is equivalent to the large electric circuit model. Students complete the worksheet on page 9 of this document.

Analogy: Electricity vs. Water Flow

Since the flow of electricity cannot be seen except in severe circumstances (lightning, metal touch shocks in dry weather), we compare electricity to the flow of water to more easily understand it. This analogy can be used by the demonstration instructor as deemed appropriate.

The electron is the SMALLEST, KNOWN particle in our world. When an electron moves, it is electricity! We call the flow of electrons or electricity “current”. Voltage is what pushes electrons to flow and creates useful current and electricity. Other particles, such as ions (atoms with too many or too few electrons) can also conduct electricity. Here, we focus on electron flow, because electrons conduct a majority of electricity we use in our everyday lives.

Just like water, electrons (current) will not flow down a wire (pipe) from which they cannot return. We say that current requires a closed “loop” or “circuit” in order to flow and conduct electricity. Electricity flowing from the power plant may power our appliances, losing energy along the way, but it always returns to the power plant. When electricity encounters a break in the wire or pipe along which it is flowing, we call this an “open circuit”. If electricity encounters no obstacles along its path, we call this a “short circuit”. We make the following analogies between electricity and water flow:

- **Driving force:**
 - voltage causes current to flow in a circuit
 - pressure causes water to flow in pipes
- **Valves (spickets):**
 - Fully “turned on” valves are similar to electrically turned on switches
 - Fully “turned off” valves are similar to electrically turned off switches
- **Resistors**
 - A partially “turned on” valve is like a resistor
 - The more “turned on” a valve is, the smaller its resistance and the more water that flows.
 - The smaller an electrical resistance is, the more current that flows.
- **Parallel (“One or both”):**
 - Valves in two different pipes are in parallel; if one is turned off, water still flows in the other pipe.
 - If one of two parallel, electrical switches is turned off, current still flows through the other switch.
- **Series (“Both or none”):**
 - Valves in the same pipe are in series; if one is turned off, water will not flow.
 - If one of two series, electrical switches is turned off, current stops flowing in the wire.
- **Generation of Force:**
 - A pump generates pressure to cause water flow.
 - A battery or wall outlet generates voltage to cause current flow.
- **One-Way flow:**
 - A check valve allows water to flow only one way in a pipe (e.g. sprinkler systems)
 - A diode allows current to flow only one way in a wire.

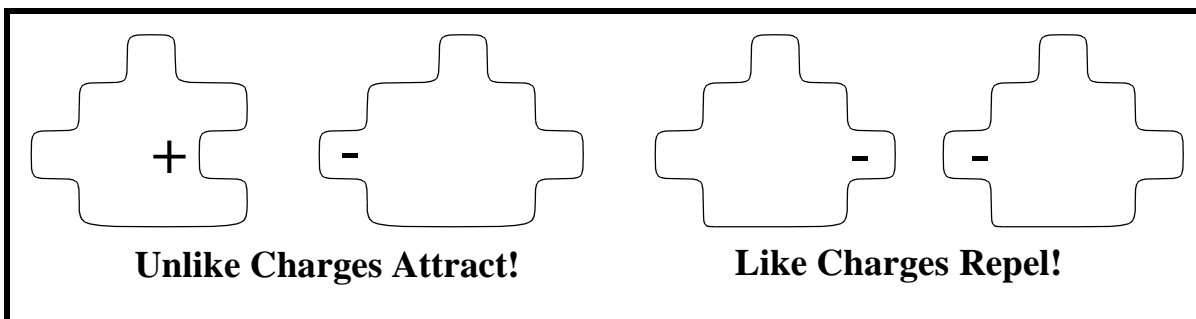
Interactive Lecture: Static Electricity

Part 1: Two types of charges

Two types of charges exist that cause static electricity. These two types of charges are called “positive” and “negative”. Negative charge is carried by an electron. Positive charge is carried by an atom, molecule, or particle which has lost one or more of its electrons. All materials, particles, and atoms WANT to be electrically neutral and they will TRY ALMOST ANYTHING to become neutral (uncharged).

In Part 1 of the demonstration, you will use the jigsaw puzzle to demonstrate, by visual analogy, that unlike charges attract, while like charges repel. This means that a negative charge will be attracted to a positive charge and repelled by a negative charge. Negative charges are attracted to positive charges so that they can combine and become electrically neutral.

Select four pieces from the jigsaw puzzle: two pieces (one “male”, one “female”) that fit together; one extra “female” piece, and one extra “male” piece. Show that the first two pieces fit together: just like positive and negative charge, they are attracted and combine to create a stable fit (neutral). Show that the two “male” pieces do not fit together; these pieces are analogous to like charges (both positive or both negative). Show that the two “male” pieces also do not fit together for similar reasons.



Part 2: Transfer of Charges

Both of these two experiments demonstrate again that unlike charges attract while like charges repel AND that electrons can be transferred from one material to another.

- Spread a little bit of puffed rice on a smooth surface, such as a table. Rub the comb with wool (you are transferring charge to the comb). Place the comb near the puffed rice. The rice will ATTACH itself to the comb as it tries to attach itself to an object whose CHARGE is UNLIKE itself. Pick up the comb to demonstrate that the rice remains attached to the comb. Since the comb is so large and the rice so small, it will take a long time (minutes) for the comb to release the rice as enough charge is transferred from the rice to the comb and back to make both the rice and the comb electrically NEUTRAL. The challenge to this experiment is holding your hand still long enough for the comb to release the rice!
- Blow up two balloons and tie them off. Rub one balloon with the wool. Place one balloon on a table or other large surface. The two balloons will be attracted to each other (unlike charges). Rub the other balloon with wool. Now, the two balloons will repel each other (like charges). Place a charged balloon near the puffed rice. What happens? Why?

Interactive Lecture: Dynamic Electricity

This part of the lecture requires the use of the large electric circuit model. Plug the power cord into a wall outlet. Turn all switches on the front of the board on; both yellow lights should light. If not, switch the polarity of the voltage adaptor by pulling out and turning around the rectangular connection plug connected to the adapter. Turn all switches off to begin the demonstration.

Part 1: Alternating current (AC) vs. Direct Current (DC)

The adapter (square black box) that connects to the wall outlet converts the alternating current coming out of the wall to direct current required for this circuit. Alternating current is what it sounds like: the current varies over time, up and down, in a wavelike fashion, so that current flows both in and out of the wall outlet when you plug something into it. Power plants use alternating current because it is CHEAPER to transmit to the customer and does not make the power wires wear out as quickly. Many circuits, however, need direct current to work, where current (electricity flow) is constant (the same) over time. Ask students where they have seen adapters; typical electronic appliances that need adapters to convert from AC to DC power or current are video games (Nintendo), keyboards, and answering machines. Typical values of DC current are 24, 12 and 9 Volts. Typical alternating current is 110V for most household appliances except for washers, dryers and the occasional hot tub which takes 220V.

Part 2: Current and Voltage

Turn on all the switches on the front of the board to the “on” position. Both yellow lights turn on. When we turned on the switches, we allowed the voltage from the adapter to push the current through the circuit. Remember that current won’t flow until it has a way to come back to where it started. When we turned the switches on, we made a closed loop or circuit which allowed the current to flow through the lights and back to the power supply (wall outlet). Notice also how the lights in the two vertical paths are dimmer when both vertical switches are on. This behavior can be directly attributed to the fact that current must split between the two paths when both switches are on; since each path has only part of the current, each light is dimmer.

Part 3: Series and Parallel

Show that when you switch one of the two vertical switches off, the other yellow light stays on (switches in parallel); when you turn the horizontal switch off (a switch in series), all the lights go off regardless of whether the other switches are on or off. Most students are familiar with series and parallel holiday lights; when a bulb burns out on a string of lights in series, all lights turn off (cheaper, but a real HEADACHE to fix). For parallel or semi-parallel holiday lights, all good lights continue to burn even when a light breaks or burns out.

Part 4: Resistance

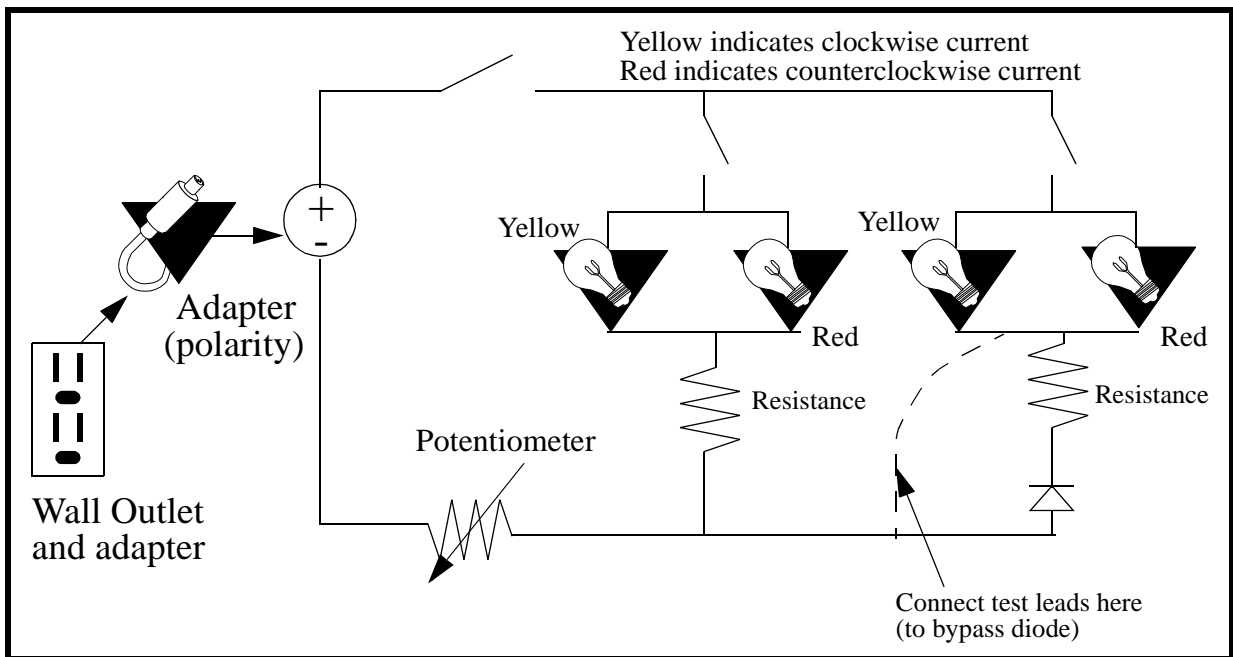
With all switches turned on, turn the knob in the lower left of the circuit model (potentiometer). As you turn the knob one way, the resistance in the circuit increases, causing the lights to dim as less current flows. As you turn it the other way, the resistance in the circuit decreases, causing the lights to become brighter as more current flows. Electrical resistance is analogous to making the pipe through which water flows more narrow.

Part 4: Voltage Polarity and Current Flow

To change the direction of the current, turn all the switches to the “off” position and turn the connector on the adapter wire (power cord) around, opposite to its original position. Turn all switches to the “on” position. The red light turns on, indicating that current is now flowing counter-clockwise rather than clockwise as it was with the adapter wire in its original position. We have just changed the polarity of the voltage that pushes current through the circuit. Polarity determines which way current will flow. Current always flows from the negative to the positive side of a voltage source. With the yellow lights on, the positive end of the voltage source was on top of the circuit, the negative on the bottom. Where is the negative end of the source when the RED light is on: on top or on bottom of the circuit? Often times, the negative end is ground in many household circuits.

Part 5: One Way current flow (diode)

Note how the red light in the left vertical path comes on while the right one does not even though the switch is in the “on” position. This behavior is due to the presence of the diode in the lower circuit branch; the diode will only allow current to flow clockwise in this particular model. It is a one way street to current! When current tries to flow counterclockwise, the diode blocks it, and current cannot flow through the red branch. To cause current to flow counterclockwise and turn the red light on, you can use the red test clips (a wire) to bypass the diode: connect one end of the test clips to a point underneath the red light and the other to a point past the diodes. Current is now bypassing the diode (one way street) and flowing through the wire. What happens to the red light?



Experimentation: Dynamic Electricity

Pass out a hands-on board to each group of 2-3 students. Before handing them out, please encourage the students to be very careful; electronic components are extremely fragile and should be handled carefully. It is especially important for students not to touch the wires on the back of each board and to hold the variable resistor steady while attempting to adjust it.

The protoboard operates identically to the electricity model. Students should make sure the batteries are inserted pointing up (with the positive polarity at the top of the circuit). Turn all switches on. The lights should turn on yellow. Turn the potentiometer knob on the bottom of the circuit. Turning it one way makes the lights dim (increases the resistance). Turning it the other way makes the lights bright (decreases the resistance).

To change the direction of the current simply flip both batteries (negative end at the top of the circuit) to reverse their polarity, and the red light should come on. One red light will not light because of the diode present in that path. Give each student a resistor and show how to bypass the diode. Bend the wire leads of the resistor by 90 degrees so it forms a “U” shape with the resistor at the bottom of the “U”. Then place one of the resistor leads on the wire at each side of the diode and the red light should come on, provided the switch is in the “on” position. Explain that the diode prevents current from flowing in the one direction, but when you create a current path that is parallel to the diode, current can then flow around the diode (bypass).

Advanced Concept: Equivalent Resistance (Optional). When the extra resistor is placed across one of the other resistors instead of the diode, one will notice that the light in that path gets brighter. This is because the equivalent resistance of two resistors in parallel is less than either of the individual resistors, so more current flows through that path and the light becomes brighter.

