SUPERCHARGED SCIENCE

Unit 10: Electricity

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Appropriate for Grades:
Lesson 1 (K-12), Lesson 2 (K-12)
Duration: 10-30 hours, depending on how many activities you do!

Electrons are strange and unusual little fellows. Strange things happen when too many or too few of the little fellows get together. Some things may be attracted to other things or some things may push other things away.

Occasionally you may see a spark of light and sound. The light and sound may be quite small or may be as large as a bolt of lightning. When electrons gather, strange things happen. Those strange things are static electricity.

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Materials for Experiments

How many of these items do you already have? We've tried to keep it simple for you by making the majority of the items things most people have within reach (both physically and budget-wise), and even have broken down the materials by experiment category so you can decide if those are ones you want to do.

NOTE: This material list is for the entire Experiment section online.

Basic Electricity

Regular sized latex balloon

1 sheet of tissue paper

Fluorescent bulb (borrow the long 'tube' kind from your house, or get a burnt out one from the recycling)

Plastic grocery bag

Wool sweater, socks, or mittens to wear

Wire coat-hanger (not insulated)

Packing peanuts (about 20)

Yard stick (AKA meter stick)

Soup spoon (bigger is better)

2 tablespoons dill

Vegetable oil (or mineral oil)

Lid from a jar (jam, pickle, mayo…)
Bubble solution (store-bought, or use our recipe:
(12 c cold water + 1 c clear Ivory dish soap)

Electric Circuits & Burglar Alarms

2 wire coat-hangers (not insulated)

1 sheet of tissue paper

3 shiny copper pennies

25 large popsicle sticks (tongue depressor size)

Brass (use brass fasteners, wood screws or keys)

Iron (find two uncoated nails if you can)

Silver ('real' silverware)

Zinc (find two galvanized nails)

Graphite (from a mechanical pencil)

Baking soda (2 tablespoons)

Film canister (or other small container with lid)

2 pcs cardboard (or 6"x 4"x 2" wood scrap)

4' length aluminum foil (used for several experiments)

1" square sponge square of squishy foam (or thin sponge) that reforms into shape when released

10 small paper clips

12 large paper clips

12 brass fasteners

2 wooden spring-type clothespins

5 unpainted steel thumbtacks

Thin bare wire (28g) or rip open an alligator clip

2 index cards

Salt (about 8 tablespoons)

Skillet and stove

2 clean glass jars (pickle, jam, mayo…)

8 AA battery packs (RS #270-408)

LEDs (Radio Shack part #276-026, 276-012, 276-016, 276-311, or similar

Neon Lamp (RS #272-712)

Buzzer (Radio Shack #273-053) or siren (#273-079)

3VDC motor (RS #273-223)

10-20 alligator clip leads (RS #278-1157)

SPST push-button switch (RS #275-646) or similar

1K or 5K-ohm potentiometers (RS #271-1714) OR 25-Ohm Rheostat (RS #271-0265)

CdS cell (RS #276-1657)

Red laser pointer (from Unit 9) or flashlight

AA batteries for your battery case (Cheap dollar-store "heavy duty" type are perfect. Alkaline batteries are NOT recommended.)

Robotics & Remote Controls

You'll need the parts from 'Electric Circuits' and these items:

6 3VDC motors (RS #273-223)

7 wheels (tops from film canisters, small yogurt containers, milk jugs, orange juice, etc.)

4 straws

1 long bolt (2" or longer) with nut

2 toothbrushes or plastic spoons

2 blocks of foam (2" x 4" x 6" or larger)

1 wooden spring-type clothespin

20 wooden skewers (for 3 different robots)

1 propeller** that fits onto the motor shaft

2 gears** or cork

Plastic soap container (optional)

Basic tools (scissors, tape, hot glue gun, and drill with bit the size of the motor shaft)

**If you have trouble finding these parts (ones with ** next to them) just send us an email.

For Grades 9-12:

You'll need the parts from the lists above and these items:

Digital Multimeter - You'll need one of these for the rest of your projects. Find one in your price range from Radio Shack.

Air Battery

Paper towel

Activated charcoal (from a fish store)

Aluminum foil

Alien Detector

LED (any regular LED works fine)

MPF 102 from Radio Shack (RS #276-2062) – buy 2, because these are the first things to burn out in your circuit

9V battery clip and a 9V battery (RS #270-325) – you should have a spare from the *Laser Communicator* project in Unit 9 you can use

Tools:

Wire strippers

Pliers, scissors

Soldering iron, solder, stand

Superfast Bug Bot

1 large paper clip

1 round bead that fits onto the large paperclip

2 small paperclips

Soda can (empty and clean)

AA battery holder with AA's

2 momentary switches (RS #275-0016)

2 hobby motors with gear (RS# 273-0258)

2 3/16" female spade connectors (RS # 64-3132)

Heat shrink tubing (RS# 278-1610)

Optional: slide switch (RS #275-0407)

Insulated wire (you can also use the wire from your battery holder, as you'll snip most of it off anyway)

Tools:

Wire strippers

Pliers, scissors

Soldering iron, solder, stand

Underwater Remotely Operated Vehicle

The underwater robot (R.O.V.) is a much larger-scale project than usual. Expect to spend at least 14 hours on building this ultra-cool remotely operated underwater vehicle that swims in lakes and pools.

½" PVC pipe (6 pieces: 1.5" long, 4 pieces 2.5" long, 4 pieces 3" long, 2 pieces 4" long, 2 pieces 4.5" long, and 2 pieces 12" long… total length is roughly 6 feet of pipe.)

2" diameter (two pieces 6" long each)

Four 2" PVC end caps

Four ½" PVC tees (slip-slip-slip)

Ten 90 deg. Elbow (slip-slip)

Coarse sand paper

Three 1" pipe clamps (U-shape with 2 mounting holes)

Three propellers that fit onto the motor shaft

Three 12VDC motors (Radio Shack part #273-256)

Three film canisters (black Kodak canisters work great)

Three DPDT switches with a center OFF (RS#275-1533)

Wire: 12' two-line (four-wire) telephone line

Wire: 20-50' lamp cord (the longer you make this length, the further out your ROV can go)

Project box (you'll need a plastic box: tupperware, soap dishes, or project boxes from Radio Shack)

6-10 zip ties

Wire (or plastic) mesh screen, 12" x 8" piece

Tools:

Soldering iron with solder

Pliers, screwdriver

Drill with drill bits

Silicone or toilet seal wax (and old mug to liquefy it in)

Vaseline

Power supply (12VDC car battery or car charger)

Key Vocabulary

If an **atom** has more electrons spinning in one direction than in the other, that atom has a magnetic field. Atoms are made of a core group of neutrons and protons, with an electron cloud circling the nucleus.

The proton has a positive **charge**, the neutron has no charge (neutron, neutral get it?) and the electron has a negative charge. These charges repel and attract one another kind of like magnets repel or attract. Like charges repel (push away) one another and unlike charges attract one another. Generally things are neutrally charged. They aren't very positive or negative, rather have a balance of both.

When electric current passes through a material, it does it by electrical **conduction**. There are different kinds of conduction, such as metallic conduction, where electrons flow through a conductor (like metal) and electrolysis, where charged atoms (called ions) flow through liquids. Metals are **conductors** not because electricity passes through them, but because they contain electrons that can move.

LED stands for "Light Emitting Diode". **Diodes** are one-way streets for electricity – they allow electrons to flow one way but not the other.

Electrons technically don't orbit the core of an atom. They pop in and pop out of existence. Electrons do tend to stay at a certain distance from a nucleus. This area that the electron tends to stay in is called a shell. The electrons move so fast around the shell that the shell forms a balloon like ball around the nucleus.

A **field** is an area around a electrical, magnetic or gravitational source that will create a force on another electrical, magnetic or gravitational source that comes within the reach of the field. In fields, the closer something gets to the source of the field, the stronger the force of the field gets. This is called the inverse square law.

A **radio remote control** has a transmitter and receiver that pass light beams to control the robot.

Robots are electro-mechanical devices, meaning that they rely on both electronics and mechanics to do their 'thing'. If a robot has sensors, it can react with its environment and have some degree of intelligence. Sensors include switches, buzzers, and light detectors.

Objects that are electrically charged can create a **temporary charge** on another object.

The **triboelectric** series is a list that ranks different materials according to how they lose or gain electrons.

A **wired remote control** is a box usually containing the batteries and switches for the connected robot.

Unit Description

Electrons are strange and unusual little fellows. Strange things happen when too many or too few of the little fellows get together. Some things may be attracted to other things or some things may push other things away.

Occasionally you may see a spark of light and sound. The light and sound may be quite small or may be as large as a bolt of lightning. When electrons gather, strange things happen. Those strange things are static electricity.

Now that you've spent a few lessons learning about the strange world of the atom (Unit 3 & Unit 8), it's time to play with them.

A lot of folks get nervous around electricity. You can't always 'see' what's going on (will I get a shock when I touch *that?*), and many people have a certain level of fear around anything electrical in general. I mean, electrons are small, and you can't see electricity, but you can certainly see its effects (like with blenders, door bells, and alarm clocks).

Electricity is predictable. The voltages and amperage we're working with in the unit are *way* below the "caution" limit, and the batteries we recommend won't leak acid if your kids connect them the wrong way. (And you should expect them to short-circuit things - it's part of the learning process.) I am going to help you set up a safe learning environment so your kids are free to experiment without you losing sleep over it.

I'm going to walk you through every step of the way, and leave you to observe the reactions and write down what you notice. We'll learn how to turn on electrical components, like buzzers and motors, and then I'll show you how to connect them together to build robots. It's not enough just to learn about these ideas - you have to use them in a way that's useful (and practical). That's when the learning really sticks to their brain.

Keep working at Electricity and eventually it will click into place. And if there's an experiment you don't want to do, just skip it (or just watch the video).

Objectives

Lesson 1: Circuits and Components

What *IS* electricity, anyway?
You can't see it, but you can certainly detect its effects. Blenders, washing machines, vacuum cleaners, airplanes - all of these use electricity. While you don't need to understand electricity to turn on a light, you *do* need to cover the basics in order to make the burglar alarms, remote controls, and robot projects in this unit! I'll show you how to convert your kitchen table into a real Electric Lab. Are you ready?

Highlights:

- The proton has a positive charge, the neutron has no charge (neutron, neutral get it?) and the electron has a negative charge.
- These charges repel and attract one another kind of like magnets repel or attract. Like charges repel (push away) one another and unlike charges attract one another.
- Generally things are neutrally charged. They aren't very positive or negative, rather have a balance of both.
- Objects that are electrically charged can create a temporary charge on another object.
- The triboelectric series is a list that ranks different materials according to how they lose or gain electrons.
- LED stands for "Light Emitting Diode". Diodes are one-way streets for electricity – they allow electrons to flow one way but not the other.
- When electric current passes through a material, it does it by electrical conduction.
- There are different kinds of conduction, such as metallic conduction, where electrons flow through a conductor (like metal) and electrolysis, where charged atoms (called ions) flow through liquids.
- Metals are conductors not because electricity passes through them, but because they contain electrons that can move.

Objectives

Lesson 2: Robotics

If you've ever wondered *how* to build a real robot from junk, then you're in the right place. Let's start by taking a look at the highlights for understanding electricity, circuits, and components and how they all work together to form a working robot.

Highlights:

- Robots are electro-mechanical devices, meaning that they rely on both electronics and mechanics to do their 'thing'.
- If a robot has sensors, it can react with its environment and have some degree of intelligence.
- Sensors include switches, buzzers, and light detectors.
- One of the biggest hurdles to overcome when building robots is friction.
- A radio remote control has a transmitter and receiver that pass light beams to control the robot.
- A wired remote control is a box usually containing the batteries and switches for the connected robot.

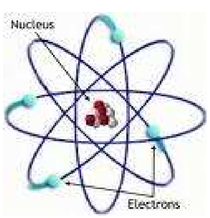
Textbook Reading

Electrons are strange and unusual little fellows. Strange things happen when too many or too few of the little fellows get together. Some things may be attracted to other things or some things may push other things away.

Occasionally you may see a spark of light and sound. The light and sound may be quite small or may be as large as a bolt of lightning. When electrons gather, strange things happen. Those strange things are static electricity.

Now that you've spent a few lessons learning about the strange world of the atom (Unit 3 & Unit 8), it's time to play with them.

Electrical Charges



Different parts of the atom have different electrical charges. The proton has a positive charge, the neutron has no charge (neutron, neutral get it?) and the electron has a negative charge.

These charges repel and attract one another kind of like magnets repel or attract. Like charges repel (push away) one another and unlike charges attract one another.

So if two items that are both negatively charged get close to one another, the two items will try to get away from one another. If two items are both positively charged, they will try to get away from one another. If one item is positive and the other negative, they will try to come together.

How do things get charged?

Generally things are neutrally charged. They aren't very positive or negative. However, occasionally (or on purpose as we'll see later) things can gain a charge.

Things get charged when electrons move. Electrons are negatively charged particles. So if an object has more electrons than it usually does, that object would have a negative charge.

If an object has less electrons than protons (positive charges), it would have a positive charge. How do electrons move? It turns out that electrons can be kind of loosey goosey.

Depending on the type of atom they are a part of, they are quite willing to jump ship and go somewhere else. The way to get them to jump ship is to rub things together. Let's play with this a bit and see if we can make it more clear.

Temporary Charge

We've already talked about this temporary charge thing, where objects that are electrically charged can create a temporary charge on another object. Let's take some time to look at that now.

Remember, in static electricity, electrons are negatively charged and they can move from one object to another. This movement of electrons can create a positive charge (if something has too few electrons) or a negative charge (if something has too many electrons). It turns out that electrons will also move around inside an object without necessarily leaving the object. When this happens the object is said to have a temporary charge.

Blow up a balloon. If you rub a balloon on your head, the balloon is now filled up with extra electrons, and now has a negative charge. Try the following experiment to create a temporary charge on a wall: bring the balloon close to the wall until it sticks.

Opposite charges attract right? So, is the entire wall now an opposite charge from the balloon? No. In fact, the wall is not charged at all. It is neutral. So why did the balloon stick to it?

The balloon is negatively charged. It created a temporary positive charge when it got close to the wall. As the balloon gets closer to the wall, it repels the electrons in the wall. The negatively charged electrons in the wall are repelled from the negatively charged electrons in the balloon.

Since the electrons are repelled, what is left behind? Positive charges. The section of wall that has had its electrons repelled is now left positively charged. The negatively charged balloon will now "stick" to the positively charged wall. The wall is temporarily charged because once you move the balloon away, the electrons will go back to where they were and there will no longer be a charge on that part of the wall.

This is why plastic wrap, styrofoam packing popcorn, and socks right out of the dryer stick to things. All those things have charges and can create temporary charges on things they get close to.

Charge It Up

Is there a difference between the zap you get from scuffing your socks on the carpet and a bolt of lightning?

Yes! There is *one* difference, and it is *quantity*. When you scuff along the carpet, you're gathering up electrons from the floor. When you touch someone, the electrons jump right over, zapping the both of you. Lightning does the same thing, just with *a lot* more power.

So how do you know what charge something takes on? How do you know if the balloon is positively or negatively charged?

The *triboelectric series* is a list that ranks different materials according to how they lose or gain electrons. Near the top of the list are materials that take on a positive charge, such as air, human skin, glass, rabbit fur, human hair, wool, silk, and aluminum. Near the bottom of the list are materials that take on a negative charge, such as amber, rubber balloons, copper, brass, gold, cellophane tape, Teflon, and silicone rubber.

When you rub a glass rod with silk, the glass takes on a positive charge and the silk holds the negative charge. When you rub your head with a balloon, the hair takes on a positive charge and the balloon takes on a negative charge.

When you scuff along the carpet, you build up a static charge (of electrons). Your socks insulate you from the ground, and the electrons can't cross your sock-barrier and zip back into the ground. When you touch someone (or something grounded, like a metal faucet), the electrons jump from you and complete the circuit, sending the electrons from you to them (or it).

Hot Electric Tip: Static electricity experiments work best on a warm, dry day. If you're stuck inside on a rainy day, close the windows and crank up the heater to dry out the air first before doing any static electricity experiments.

Electrical Circuits

Although we can't 'see' electricity flow through wires, you can certainly see, hear, and feel its effects: the light bulb flashing on, the hair dryer blowing, the radiant heat generated by electric power, and so forth.

An electrical circuit is like a NASCAR raceway. The electrons (racecars) zip around the race loop (wire circuit) superfast to make stuff happen. Although you can't see the electrons zipping around the circuit, you can see the effects: lighting up LEDs, sounding buzzers, clicking relays, etc.

There are many different electrical components that make the electrons react in different ways, such as resistors (limit current), capacitors (collect a charge), transistors (gate for electrons), relays (electricity itself activates a switch), diodes (one-way street for electrons), solenoids (electrical magnet), switches (stoplight for electrons), and more. We're going to use a combination of LEDs, buzzers, and motors in our circuits in our unit together.

A CIRCUIT looks like a CIRCLE. When you connect the batteries to the LED with wire and make a circle, the LED lights up. If you break open the circle, electricity (current) doesn't flow and the LED turns dark.

LED stands for "Light Emitting Diode". Diodes are one-way streets for electricity – they allow electrons to flow one way but not the other.

Remember when you scuffed along the carpet? You gathered up an electric charge in your body. That charge was static until you zapped someone else. The movement of electric charge is called electric current, and is measured in amperes (A).

When electric current passes through a material, it does it by electrical conduction. There are different kinds of conduction, such as metallic conduction, where electrons flow through a conductor (like metal) and electrolysis, where charged atoms (called ions) flow through liquids.

When an atom (like hydrogen) or molecule (like water) loses an electron (negative charge), it becomes an ion and takes on a positive charge. When an atom (or molecule) gains an electron, it becomes a negative ion. An electrolyte is any substance (like salt) that becomes a conductor of electricity when dissolved in a solvent (like water).

This type of conductor is called an 'ionic conductor' because once the salt is in the water, it helps along the flow of electrons from one clip lead terminal to the other so that there is a continuous flow of electricity.

In this case we're using water as a holder for different substances, like salt. But you can use orange juice, lemon juice, vinegar, baking powder, baking soda, spices, cornstarch, flour, oil, soap, shampoo, and anything else you have around.

Electrical Switches & Burglar Alarms

Burglar alarms not only protect your stuff, they put the intruder into a panic while they attempt to disarm the triggered noisemaker. Our burglar alarms are clever switches which use cool tricks in electrical conductivity. I'll also show you how to turn these burglar alarms into sensors for your robots. But first, let's recap a bit about electrical charge and conduction.

Think of this switch like a train track. When you throw the switches one way, the train (electrons) can race around the track at top speed. When you turn the switch to the OFF position, it's like a bridge collapse for the train – there's no way for the electrons to jump across without the track. When you switch it to the ON position (both sides), you've rebuilt the bridges for the train (electrons).

When electric current passes through a material, it does so by electrical conduction, but there are different *kinds* of conduction, such as metallic conduction (metals) and electrolysis (where charged atoms (called ions) flow through liquids).

Why does metal conduct electricity?

Metals are conductors not because electricity passes *through* them, but because they contain electrons that can move. Think of the metal wire like a hose full of water. The water can move through the hose. An insulator would be like a hose full of cement - no charge can move through it. Paper, rubber, and plastics make great insulators, because sometimes you don't want electricity to flow unless you say so. And that's exactly how we're going to make our burglar alarms.

Caution about Batteries

We recommend using the super-cheap kind of batteries (usually labeled "Heavy Duty" or "Super Heavy Duty"), usually found at 'dollar stores', because these types of batteries are carbon-zinc, which do not contain acid (the way alkaline batteries do). So when your kid shorts the circuits and overheats the batteries (which you should expect, by the way), it's not dangerous. Alkaline batteries (like Energizer and Duracell) will get super-hot and lead acid, so those aren't the ones you want your kids to play with. You can also take these types of batteries apart when they've exhausted their charge.

Robotics

Robots are electro-mechanical devices, meaning that they rely on both electronics and mechanics to do their 'thing'. If a robot has sensors, it can react with its environment and have some degree of *intelligence*.

When scientists design robots, they first determine what they want the robot to do. *Turn on a light? Make pancakes? Drive the car?* Once you've outlined your tasks, then the real fun begins… namely, figuring out exactly *how* to accomplish the tasks.

Leonardo da Vinci designed a mechanical knight back in the late 1400s. His drawing sketched out how it could sit upright and move arms, legs, and jaws. Jacques de Vaucanson, in the late 1700s, created the first life-sized mechanical automatons, including a mechanical duck that could flap its wings. It was the Japanese toy industry that really kicked off the mechanical revolution of inventions with complex mechanical inventions that could either paint pictures, fire arrows from a quiver, or serve tea. Not long after, in 1898, Nikola Tesla demonstrated the first radio-controlled torpedo. In 1948, the first electronic autonomous robots (robots that do their 'thing' automatically) were *Elmer* and *Elsie*, who could sense light, contact, and navigate through a room.

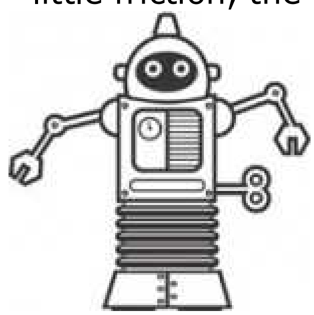
By putting together motors, switches, lights, buzzers, light detectors, tilt and motion sensors, and pressure sensors, you can develop a homemade robot worthy of the science fair's winner's circle.

In addition to interacting with their environment, robots need to be able to move somehow. Robots can move by spinning wheels, turning propellers, moving pistons, grinding gears, or by eccentric (off-center) drive.

The robots outlined here cover three different movement types: a swimming robot (waterbot), a dancing robot (jigglebot), and a steerable robot (racerbot). While the instructions for these robots focus mainly on the chassis (body or frame) and locomotion (movement), you will want to add lights, buzzers, and any sensors from the *Burglar Alarms* section to make the robot your very own.

One of the biggest hurdles to overcome when building junkyard robots is friction. Since the motors have high speed and low torque, they can be difficult to use without a gearbox (which is both hard to find *and* out of the scope of our work in this unit).

One of the ways we're going to reduce friction is by submerging the robot in water. Since water has little friction, the robot will move about quite easily in the wet environment. Just be sure to keep the batteries out of the water.



Activities, Experiments, Projects

Lesson 1: Circuits and Components

Note: This section is an abbreviated overview of the experiments online.

Experiment: Static Electricity

The smallest thing around is the atom, which has three main parts - the core (nucleus) houses the protons and neutrons, and the electron zips in a ring around the core, much like the chunks of rocks and ice zip around the planet Saturn.

The proton has a positive charge, and the electron has a negative charge. In the hydrogen atom, which has one proton and one electron, the charges are balanced. If you steal the electron, you now have an unbalanced, positively charge atom and stuff really starts to happen. The flow of electrons is called electricity. We're going to negative charges) until the balloon stole your negative electrons, leaving you with an unbalanced positive charge. Let' play with a more static electricity experiments, including how to make water wiggle by just using a charged balloon!

move electrons around and have them stick, not flow, so we call this 'static electricity'.

These next experiments rely heavily on the idea that like charges repel and opposites attract. Your kids need to remember that these activities are all influenced by electrons, which are very small, easy to move around, and are invisible to the eye.

Blow up a balloon. If you rub a balloon on your head, the balloon steals the electrons from your head, and now has a negative charge. Your head now has a positive charge because your head was electrically balanced (same number of positive and

Expt. 1: Static Hairdo Charge a balloon by rubbing it on your head for 30 seconds. Pull the balloon up about six inches to check your progress - if the hair isn't sticking to the balloon, try again on someone with clean, dry hair (without any hair styling goop). When you put the balloon close to your head, notice how your hair reaches out for the balloon. Your hair is positive, the balloon is negative, and you can see how they are attracted to each other!

Your hair stands up when you rub it with a balloon because your head is now positively charged, and all those plus charges don't like each other (repel). They are trying to get as far away from each other as possible, so they spread far apart. Does the hair continue to stand apart even after you remove the balloon? Does it matter what hair color or texture? (Does the balloon shape matter?)

Bonus Question: How can you get rid of the extra electrons?

Expt. 2: Finding Attraction Rub your head with the balloon and then hold the balloon to a wall. Can you make it stick? How about the ceiling? How many other things does the balloon stick to? (Hint - try a wool sweater.)

Expt. 3 Wiggly Wonder Hold the charged balloon near a stream of water running from a faucet. Can you make the water wiggle without touching it? The charged balloon attracts the stream of water. The water is like a bar magnet in that there are poles on a water molecule: there's a plus side and a minus side, and the water molecules line up their positive ends toward the balloon when you bring it close.

Expt. 4 Ping Pong Puzzle Rub a comb with a wool sweater, and bring it close to a ping pong ball resting on a flat table. Why do you think the ping pong ball moves? Does it work if you use a charged balloon instead? What if you swap the ping pong ball for a piece of styrofoam?

Expt. 5: Static Neon Store up a good charge of electrons by scuffing along the carpet in socks on a warm, dry day. To make this a much more interesting experiment, hold one end of a neon bulb (RS #272-712) and watch it light as you touch the other end to a nearby object such as a metal faucet, metal part of a lamp, etc. You can also bring it close to your TV set (the old tube TV kind), both turned on and just turned off, to see if it has any effects on the neon lamp bulb?

Hint: you'll need to get the neon bulb *out* of the plastic encasing and hold only one of the wires to make this experiment work - one wire act a as the *collector*, the other is *grounded* (via your hand) to the earth. You can also hold onto one lead as you slide down a plastic slide and then touch something grounded (like your mom).

You steal electrons and take on a negative charge when you scuff along the carpet in socks. Remember that just like magnets, 'like' charges (negative-to-negative or positive-to-positive) repel, and opposite charges (negative-to-positive) attar, which is why you can make your hair stand up on end by scuffing around a lot. The hairs all become negative, trying to get as far away from each other as they can.

Expt. 6: Electric Tail Feathers Cut a sheet of tissue paper into 12 thin strips, about 1/2" wide and 8-12" long. Straighten out a wire coat hanger (snip off the hook part), or find yourself a 10g piece of metal uninsulated wire. Tape the strips to the end of a wire coat hanger (make sure your coat hanger do not have plastic insulation around it - use sandpaper to sand off any clear enamel if you're not sure). Attach a piece of plastic with tape or clay to the center of the rod, making a V-groove so the handle sits better on the wire. Bring a *very* charged balloon near the end of the wire - what happens?

Expt. 7: Ghost Words (Although this experiment has also held the name "Ghost Poop"...) Rub packing peanuts with wool or your hair to build up a strong, quick static charge. Stick the stryfoam to the wall to spell out words. How long do they stay attached to the wall? Does humidity matter? (Try spritzing with a *light* mist of water).

Expt. 8: Static Bubbles Blow a few big, round bubbles (use store-bought bubble solution, or make your own with 12 cups cold water and 1 cup clear Ivory dish soap and a wire coat hanger stretched into a diamond shape). Chase your bubbles with a charged balloon - what happens? Try the comb rubbed with wool - which works better? What other two things can you use to change the path of the soap bubble?

Expt. 9: Fluorescents Unplugged In a dark room, rub the length of a fluorescent bulb with a piece of plastic wrap (or polyethylene bag or wool sweater) vigorously and then pull your arm away - the bulb should light up momentarily. What other materials cause it to glow?

Why do these experiments work?

The **triboelectric series** is a list that ranks different materials according to how they lose or gain electrons. Near the top of the list are materials that take on a positive charge, such as air, human skin, glass, rabbit fur, human hair, wool, silk, and aluminum. Near the bottom of the list are materials that take on a negative charge, such as amber, rubber balloons, copper, brass, gold, cellophane tape, Teflon, and silicone rubber.

When you rub a glass rod with silk, the glass takes on a positive charge and the silk holds the negative charge. When you rub your head with a balloon, the hair takes on a positive charge and the balloon takes on a negative charge.

When you scuff along the carpet, you build up a static charge (of electrons). Your socks insulate you from the ground, and the electrons can't cross your sock-barrier and zip back into the ground. When you touch someone (or something grounded, like a metal faucet), the electrons jump from you and complete the circuit, sending the electrons from you to them (or it).

The fluorescent bulb lights up when the electrons jump around. The inside of the bulb is coated with phosphor (a white powder) and filled with mercury vapor gas. The phosphor gives off light whenever it gets smacked with UV light. The mercury vapor gives off UV light whenever it gets excited by electricity (movement of electrons). When you rub the outside of the bulb, electrons start to jump around, exciting the gas, which generated UV light, which hits the phosphor and causes it to glow briefly. When the bulb is in balance, it stays dark. If you tip the balance, electrons flow and you get light.

Experiment: Basic Circuits

There are many different electrical components that make the electrons react in different ways, such as resistors (limit current), capacitors (collect a charge), transistors (gate for electrons), relays (electricity itself activates a switch), diodes (one-way street for electrons), solenoids (electrical magnet), switches (stoplight for electrons), and more. We're going to use a combination diode-light-bulb (LED), buzzers, and motors in our circuits right now.

A CIRCUIT looks like a CIRCLE. When you connect the batteries to the LED with wire and make a circle, the LED lights up. If you break open the circle, electricity (current) doesn't flow and the LED turns dark.

LED stands for "Light Emitting Diode". Diodes are one-way streets for electricity – they allow electrons to flow one way but not the other.

Remember when you scuffed along the carpet? You gathered up an electric charge in your body. That charge was static until you zapped someone else. The movement of electric charge is called electric current, and is measured in amperes (A). When electric current passes through a material, it does it by electrical conduction. Let's make a set of circuits using our components. Here's what you do:

1. Insert fresh batteries into your battery holder.
2. Spread the LED leads a bit apart so you can clip one alligator wire to each lead without touching the other.
3. Clip an alligator clip wire from one battery wire to one LED lead wire, and repeat for the other side.
4. Your LED should light up.

Troubleshooting: Here's how to help if their circuit doesn't work:

1. Check the batteries. Are they in the right way? You'd be surprised how often this happens. Are the batteries fresh? Most LEDs require at least 2.2V to illuminate.
2. Check the connections. Are they clipping their alligator wire to the metal tip on the wire, or to the plastic insulation? Which conducts electricity better?
3. Check the direction of the LED (Light Emitting Diode). The LED is a one-way street for electricity. If it's in backwards, disconnect it, flip it around, and stick it back in the circuit. This is an excellent lesson in 'polarity' (positive and negative). LEDs are picky about plus and minus – it matters which way you hook it up.
4. Change out the wires. Sometimes wires have small breaks near the clip ends which you can't see because they are underneath the insulation. Change out one wire at a time so you're sure to find the culprit. Take it apart and fix it later.

Try substituting buzzers, motors, and other components for the LED. A nice touch is to see if your student can get all the LEDs and things to activate at the same time!

Activities, Experiments, Projects

Lesson 2: Robotics

Note: This section is an abbreviated overview of the experiments online. Robot projects are available in video format only. We're going to build a few sensors here.

Experiment: Pressure Sensor Burglar Alarm

By controlling how and when a circuit is triggered, you can easily turn a simple circuit into a burglar alarm – something that alerts you when something happens. By sensing light, movement, weight, liquids, even electric fields, you can trigger LEDs to light and buzzers to sound. Your room will never be the same.

Switches control the flow of electricity through a circuit. There are different kinds of switches. NC (normally closed) switches keep the current flowing until you engage the switch. The SPST and DPDT switches are NO (normally open) switches.

The pressure sensor we're building is small, and it requires a fair amount of pressure to activate. Pressure is force (like weight) over a given area (like a footprint). If you weighed 200 pounds, and your footprint averaged 10" long and 2" wide, you'd exert about 5 psi (pounds per square inch) per foot.

However, if you walked around on stilts indeed of feet, and the 'footprint' of each stilt averaged 1" on each side, you'd now exert 100 psi per foot. Why such a difference?

The secret is in the area of the footprint. In our example, your foot is about 20 square inches, but the area of each stilt was only 1 square inch. Since you haven't changed your weight, you're still pushing down with 200 pounds, only in the second case, you're pressing the same weight into a much smaller spot… and hence the pressure applied to the smaller area shoots up by a factor of 20.

So how do we use pressure in this experiment? When you squeeze the foam, the light bulb lights up! It's ideal for under a doormat or carpet rug where lots of weight will trigger it.

Here's what you do:

1. Find a piece of squishy foam. Like a sponge. You want something that will spring back into shape after you squeeze and release it.
2. Cut a small (1/2" diameter) hole through the middle of the sponge with a pair of scissors.
3. Lay a small piece of aluminum foil over each side of the hole. The foil needs to be smaller than the sponge but larger than the hole.
4. Lay a paper clip on top of the foil, one per side.
5. Wrap the whole thing securely with tape.
6. Set aside.
7. Using alligator wires, batteries in a holder, and an LED, create a simple circuit that makes your LED light up (see Lesson 1 for instructions).
8. Remove one of the alligator wires from the LED and insert a *third* wire to the LED.
9. Attach the remaining two alligator wires to the paper clips, one to each side.
10. Squeeze the foam. Your LED should light up!

Troubleshooting: There are a few problem areas to watch out for when building this sensor. First, make sure the hole in your foam is big enough to stick a finger (or thumb) easily through. The foam keeps the foil apart until stepped on, then it squishes together to allow the foil to make contact through the hole.

The second potential problem is if the switch doesn't turn the buzzer off. If this happens, it means you're bypassing the switch entirely and keeping the circuit in the constant ON position. Check the two foil squares - are they touching around the outside edges? Lastly, make sure your foam is the kind that pops back into shape when released. (Thin sponges can work in a pinch.)

What's happening? You've made a switch, only this one is triggered by squeezing it. If you're using the special black foam without the hole, it works because the foam conducts more electricity when squished together, and less when it's at the normal shape.

First, the special black foam is conducting some (but not enough) electricity when you squeeze it. It's just the nature of the black foam included with the materials kit. Second, when you squeeze it, you're getting the two foil squares to touch through the hole, and this is what really does it for your LED. When you release it, the foil spreads apart again because they are on opposite sides of the foam square.

Bonus Idea: Stick just the sensor under a rug and run longer wires from the sensor to your room. When someone comes down the hallway, they'll trigger the sensor and alert you before they get there!

Experiment: Trip Wire Burglar Alarm

Burglar alarms not only protect your stuff, they put the intruder into a panic while they attempt to disarm the triggered noisemaker. Our burglar alarms are basically switches which utilize the circuitry from Basic Circuits and clever tricks in conductivity.

A complete and exhaustive description of electronics would jump into the physics of solid state electronics, which is covered in undergraduate university courses. Instead, here is a quick description based on the fluid analogy for electric charge:

The movement of electric charge is called electric current, and is measured in amperes (*A, or amps*). When electric current passes through a material, it does so by electrical conduction, but there are different *kinds* of conduction, such as metallic conduction (where electrons flow through a conductor, like metal) and electrolysis (where charged atoms (called ions) flow through liquids).

Paper doesn't conduct electricity – it's an insulator. The trip wire is an NC (normally closed) switch, meaning that this circuit works *until* you trigger the switch. So we need a way to stop the current (flow of electrons) until we want the buzzer to activate.

When you stick the paper index card between the two tacks in the clothespin, it breaks the electrical connection and the switch goes in the OFF position. Remove the paper and your switch moves to the ON position, and electrons are flowing around and around your circuit, and you hear a *BUZZZZZZZZZ*!

This alarm has a thin wire that someone "trips", which pulls out the card, closes the switch, and sounds a buzzer or lights up an LED!

Optional Prep Step: Drill a tiny hole (1/16th) into both jaws of a clothespin.

1. Cut a piece of thin wire in two.
2. Wrap one end of the wire end around a tack. (Do this for both tacks.)
3. Insert the tacks into the jaws of the clothespin, as if you were inserting teeth into the jaws.
4. Close the clothes pin so the tack heads press together. (You can dab the pointy ends with hot glue so the tacks stay put.)
5. Wire up your basic circuit to be sure it works before adding it in.
6. Light up your LED or make your buzzer sound. Now "break" the circuit open by disconnecting it somewhere (like the alligator clip that connects to the red battery wire, for example).
7. Add in the trip wire switch you just made (just like we did in the pressure sensor activity above) Insert a card into the jaws, attach string to the card, and pull! BUZZ!!

What's going on? You've just made an 'NC' (normally closed) switch. Since paper doesn't conduct electricity, when you stick the index card between the two tacks, it breaks the electrical connection and the switch goes in the OFF position. Remove the paper and your switch moves to the ON position, and electrons are flowing around and around your circuit!

Troubleshooting: The trip wire is a NC (normally closed) switch. The buzzer makes noise until you 'push' (squeeze, really) the switch. To arm the trip wire, insert a small card between the tacks. The card works because paper does not conduct electricity. When the card gets yanked out, the tacks touch and… *BUZZ!!!*

Installation Tip: Hide this switch down low by the door frame and use fishing line instead of string to make this burglar alarm virtually invisible. Use a tack in the frame or tie the line to the door hinge to secure and wait for the action.

Exercises

Lesson 1: Circuits and Components

1. LED stands for "Light Emitting Diode". Does it matter which way you wire it up in a circuit? Does the longer wire on the LED connect to plus (red) or minus (black)?
2. Do you need to hook up batteries to make the neon lamp light up? What are 2 different ways you can make the neon lamp light up?
3. If you want to reverse the spin direction of a motor without using a switch, what can you do?
4. A simple switch can be made out of what kinds of materials?
5. Name six materials that are electrically conductive.
6. What's the difference between a light bulb and your LED?

7. What happens when you rub your head with an inflated balloon? Which charge is where?

8. Why do electrical charges move in a circuit?

9. What makes lightning?

10. What's the charge of an electron?

11. What happens when you split an electron open?

Exercises

Lesson 2: Robotics

1. Draw how you can connect a buzzer, LED, battery pack, and motor together AND have them all work at the same time.

2. How can you make a motor (that's already wired up in your circuit) go *faster*?

3. What does a DPDT switch do? Draw six dots (like the six on a die) – these are the six terminals on your DPDT switch. Using your diagram, draw how you would connect the DPDT switch so that it can turn the motor on and off, as well as reversing it.

4. Can you use the same electrical circuit for the underwater robot as the laser light show? Why/why not?

5. Why does the pressure sensor work?

6. What kind of switch is the trip wire?

7. Name three ways you would improve the Jigglebot Robot.

Answers to Circuits & Components Exercises

1. Yes, the longer lead is positive, and the side of the LED plastic housing that has a straight edge is negative.
2. No batteries required. The neon lamp requires very little amps, but high voltage to illuminate, which you can get by charging yourself up. Simply hold one lead and scuff along the carpet and touch the other lead to your cat's nose. Or hold one lead and slide down a non-metal slide. Poof!
3. Switch the wires on the back of the motor at the terminals.
4. Take the two wires (one from the battery and the other from the motor) and touch them together – ON – OFF – ON – OFF. Simplest switch in the world! But you can also use index cards, paper clips, and brass fasteners. Clothespins work great, too.
5. Soda cans, quarters, paper clips, braces, unpainted eyeglasses, and your tongue.
6. A light bulb works both ways when you connect it into a circuit, an LED is polarized (only works one way).
7. Blow up a balloon. If you rub a balloon on your head, the balloon is now filled up with extra electrons, and now has a negative charge. The balloon is negatively charged.
8. There's an imbalance of charges when you hook up a battery, causing the electrons to zip around the circuit.
9. There's an imbalance of charge when lightning strikes. It's the same thing a when you scuffed along the carpet, gathering up electrons in your body, only the lightning has a *lot* more charge.
10. Negative.
11. Nothing – an electron is as small as you can get. At least, as far as we know now.

Answers to Robotics Exercises

1. Connect the LED, motor, and buzzer in parallel (plus to plus) and they should all work.
2. Add a second battery pack to your circuit.
3. A DPDT switch allows you to reverse the motor direction by reversing the flow of electrons.
4. Yes – they both use the same circuit, including the motor speed control circuitry. They both need to control the speed and direction of the motors, and the electrical circuit doesn't care whether you have a mirror or propeller on your motor shaft.
5. The sponge separates the foil, breaking the circuit open. When you squish the foam, the foil pieces touch and your light bulb lights up.
6. The trip wire is a NC (normally closed) switch.
7. I'd add headlights (LEDs), horn (buzzer), and wired remote control. How about you?

