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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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, but rather have a balance of both.

When electric current passes through a material, it does so 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 **L**ight **E**mitting **D**iode. **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 an 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 can be quite small or might 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 some atoms.

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).

A note to parents and teachers—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 the brain.

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, but 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 **L**ight **E**mitting **D**iode. 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.

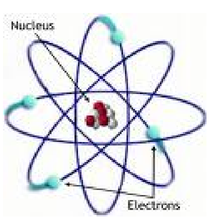
Textbook Reading

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 can be quite small or might 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 some atoms.

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 fewer electrons than protons (making it positively charged), 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 clearer.

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 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 the things that 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.

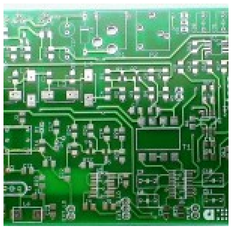
When you rub a glass rod with silk, the glass takes on a positive charge and the silk holds the negative charge. When you rub your head with a balloon, the hair takes on a positive charge and the balloon takes on a negative charge.

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 **L**ight **E**mitting **D**iode. 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 so 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 our experiment, we will be 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 experimental burglar alarm is made of 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 that has collapsed in front of a 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 bridge 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. We recommend this 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 leak acid, so those aren’t the ones you want your kids to play with. You can also take the super-cheap carbon-zinc 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. In the late 1700s, Jacques de Vaucanson, 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*, which could sense light, make contact with one another through dance, 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 a 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.