Intro to Electricity

By Chris Woodford

Updated: May 30, 2014

Name ____________________________ Date _____________ *Non-fiction Reading with questions*

Electricity

If you've ever sat watching a thunderstorm, with mighty lightning bolts darting down from the sky, you'll have some idea of the power of electricity. A bolt of lightning is a sudden, massive surge of electricity between the sky and the ground beneath. The energy in a single lightning bolt is enough to light 100 powerful lamps for a whole day or to make a couple of hundred thousand slices of toast!
Electricity is the most versatile energy source that we have; it is also one of the newest: homes and businesses have been using it for not much more than a hundred years. Electricity has played a vital part of our past. But it could play a different role in our future, with many more buildings generating their own renewable electric power using solar cells and wind turbines. Let's take a closer look at electricity and find out how it works!

What is electricity?

Electricity is a type of energy that can build up in one place or flow from one place to another. When electricity gathers in one place it is known as static electricity (the word static means something that does not move); electricity that moves from one place to another is called current electricity.

Static electricity

Static electricity often happens when you rub things together.
TRY THIS: Rub a balloon against your clothing 20 or 30 times, you'll find the balloon sticks to you and maybe even the wall. This happens because rubbing the balloon gives it an electric charge (a small amount of electricity). The charge makes it stick to your clothing like a magnet, because your clothing gains an opposite electric charge when you rub. Your clothing and the balloon attract one another like the opposite ends of two magnets.

Have you ever walked across a nylon rug or carpet and felt a slight tingling sensation? Then touched something metal, like a door knob or a faucet (tap), and felt a sharp pain in your hand? That is an example of an electric shock. When you walk across the rug, your feet are rubbing against it. Your body gradually builds up an electric charge, which is the tingling you can sense. When you touch metal, the charge runs instantly to Earth—and that's the shock you feel!
Lightning is also caused by static electricity. As rain clouds move through the sky, they rub against the air around them. This makes them build up a huge electric charge. Eventually, when the charge is big enough, it leaps to Earth as a bolt of lightning. You can often feel the tingling in the air when a storm is brewing nearby. This is the electricity in the air around you.

Photo: Lightning in South Lakewood, Colorado. Photo by Dave Parsons courtesy of US DOE/NREL (Department of Energy/National Renewable Energy Laboratory).

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• Describe electricity and how electricity "works"

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How static electricity works

Electricity is caused by electrons, the tiny particles that "orbit" around the edges of atoms, from which everything is made. Each electron has a small negative charge. An atom normally has an equal number of electrons and protons (positively charged particles in its nucleus or center), so atoms have no overall electrical charge. A piece of rubber is made from large collections of atoms called molecules. Since the atoms have no electrical charge, the molecules have no charge either—and nor does the

When you rub a balloon on your clothing, this leaves the balloon with slightly too few electrons. Since electrons are negatively charged, having too few electrons makes the balloon slightly positively charged. Your clothing meanwhile gains these extra electrons and becomes negatively charged. Opposite charges attract, so your clothing sticks to the balloon. That's a very brief introduction to static electricity.

Photo: A classic demonstration of static electricity you may have seen in your school. When this girl touches the metal ball of a Van de Graaff static electricity generator, she receives a huge static electric charge and her hair literally stands on end! Each strand of hair gets the same static charge and like charges repel, so her hairs push away from one another. Photo courtesy of Sandia National Laboratories/US Department of Energy.

Current electricity

When electrons move, they carry electrical energy from one place to another. This is called current electricity or an electric current. A lightning bolt is one example of an electric current, although it does not last very long. Electric currents are also involved in powering all the electrical appliances that you use, from washing machines to flashlights and from telephones to MP3 players. These electric currents last much longer.
Have you heard of the terms potential energy and kinetic energy? Potential energy means energy that is stored somehow for use in the future. A car at the top of a hill has potential energy, because it has the potential (or ability) to roll down the hill in future. When it's rolling down the hill, its potential energy is gradually converted into kinetic energy (the energy something has because it's moving).

Static electricity and current electricity are like potential energy and kinetic energy. When electricity gathers in one place, it has the potential to do something in the future. Electricity stored in a battery is an example of electrical potential energy. You can use the energy in the battery to power a flashlight, for example. When you switch on a flashlight, the battery inside begins to supply electrical energy to the lamp, making it give off light. All the time the light is switched on, energy is flowing from the battery to the lamp. Over time, the energy stored in the battery is gradually turned into light (and heat) in the lamp. This is why the battery runs flat.

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• What is the difference between static and current electricity?

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Picture: A battery like this stores electrical potential energy in a chemical form. When the battery is flat, it means you've used up all the stored energy inside by converting it into other forms.

Electric circuits

For an electric current to happen, there must be a circuit. A circuit is a closed path or loop around which an electric current flows. A circuit is usually made by linking electrical components together with pieces of wire cable. Thus, in a flashlight, there is a simple circuit with a switch, a lamp, and a battery linked together by a few short pieces of copper wire. When you turn the switch on electricity flows around the circuit. If there is a break anywhere in the circuit, electricity cannot flow. If one of the wires is broken, for example, the lamp will not light. Similarly, if the switch is turned off, no electricity can flow. This is why a switch is sometimes called a circuit breaker.

You don't always need wires to make a circuit, however. There is a circuit formed between a storm cloud and the Earth by the air in between. Normally air does not conduct electricity. However, if there is a big enough electrical charge in the cloud, it can create charged particles in the air called ions (atoms that have lost or gained some electrons). The ions work like an invisible cable linking the cloud above and the air below. Lightning flows through the air between the ions.

How electricity moves in a circuit

Materials such as copper metal that conduct electricity (allow it to flow freely) are called conductors. Materials that don't allow electricity to pass through them so readily, such as rubber and plastic, are called insulators.

• What makes copper a conductor and rubber an insulator?

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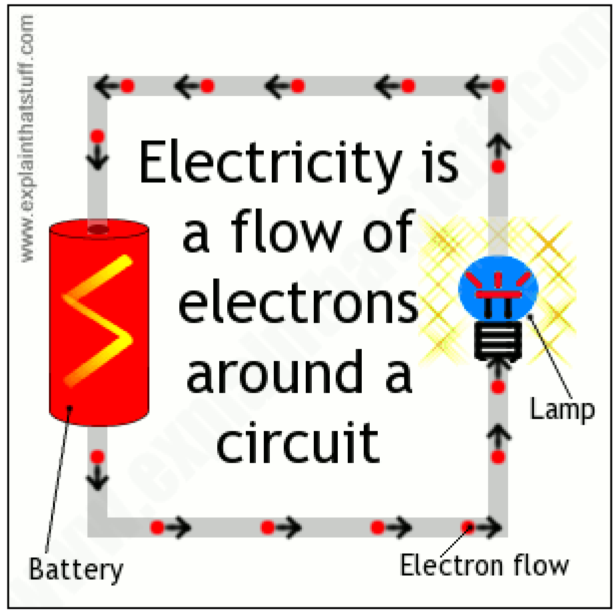

A current of electricity is a steady flow of electrons. When electrons move from one place to another, round a circuit, they carry electrical energy from place to place like marching ants carrying leaves. Instead of carrying leaves, electrons carry a tiny amount of electric charge.
Electricity can travel through something when its structure allows electrons to move through it easily. Metals like copper have "free" electrons that are not bound tightly to their parent atoms. These electrons flow freely throughout the structure of copper and this is what enables an electric current to flow.

In rubber, the electrons are more tightly bound. There are no "free" electrons and, as a result, electricity does not really flow through rubber at all. Conductors that let electricity flow freely are said to have a high conductance and a low resistance; insulators that do not allow electricity to flow are the opposite: they have a low conductance and a high resistance.
For electricity to flow, there has to be something to push the electrons along. This is called an electromotive force (EMF). A battery or power outlet creates the electromotive force that makes a current of electrons flow. An electromotive force is better known as a voltage.

Electromagnetism

Electricity and magnetism are closely related. You might have seen giant steel electromagnets working in a scrapyard. An electromagnet is a magnet that can be switched on and off with electricity. When the current flows, it works like a magnet; when the current stops, it goes back to being an ordinary, un-magnetized piece of steel. Scrapyard cranes pick up bits of metal junk by switching the magnet on. To release the junk, they switch the magnet off again.

Electromagnets show that electricity can make magnetism, but how do they work? When electricity flows through a wire, it creates an invisible pattern of magnetism all around it. If you put a compass needle near an electric cable, and switch the electricity on or off, you can see the needle move because of the magnetism the cable generates. The magnetism is caused by the changing electricity when you switch the current on or off.
This is how an electric motor works. An electric motor is a machine that turns electricity into mechanical energy. In other words, electric power makes the motor spin around—and the motor can drive machinery. In a clothes washing machine, an electric motor spins the drum; in an electric drill, an electric motor makes the drill bit spin at high speed and bite into the material you're drilling. An electric motor is a cylinder packed with magnets around its edge. In the middle, there's a core made of iron wire wrapped around many times. When electricity flows into the iron core, it creates magnetism. The magnetism created in the core pushes against the magnetism in the outer cylinder and makes the core of the motor spin around.

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TRY THIS: Make an electromagnet

You can make a small electromagnet using a battery, some insulated (plastic-covered) copper wire, and a nail. DO some research, write a procedure and make an electromagnet.

• How to make an electromagnet?:

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Making electricity

Just as electricity can make magnetism, so magnetism can make electricity. A dynamo is a bit like an electric motor inside. When you pedal your bicycle, the dynamo clipped to the wheel spins around. Inside the dynamo, there is a heavy core made from iron wire wrapped tightly around—much like the inside of a motor. The core spins freely inside some large fixed magnets. As you pedal, the core rotates inside these outer magnets and generates electricity. The electricity flows out from the dynamo and powers your bicycle lamp.

The electric generators used in power plants work in exactly the same way, only on a much bigger scale. Instead of being powered by someone's legs, pedaling furiously, these large generators are driven by steam. The steam is made by burning fuels or by nuclear reactions. Power plants can make enormous amounts of electricity, but they waste quite a lot of the energy they produce. The energy has to flow from the plant, where it is made, to the homes, offices, and factories where it is used down many miles of electric power cable. Delivering electricity this way can waste up to two thirds of the power originally produced!

Another problem with power plants is that they make electricity by burning "fossil fuels" such as coal, gas, or oil. This creates pollution and adds to the problem known as global warming (the way Earth is steadily heating up because of the energy people are using). Another problem with fossil fuels is that supplies are limited and they are steadily running out.

There are other ways to make energy that are more efficient, less polluting, and do not contribute to global warming. These types of energy are called renewable, because they can last indefinitely. Examples of renewable energy include wind turbines and solar power. Unlike huge electric power plants, they are often much more efficient ways of making electricity. Because they can be sited closer to where the electricity is used, less energy is wasted transmitting power down the wires.

Photo: Making clean, renewable energy from the wind. Each of these turbines contains an electricity generator in the top section, just behind the spinning rotors.

Wind turbines are effectively just electric generators with a propeller on the front. The wind turns the propeller, which spins the generator inside, and makes a study current of electricity.
Unlike virtually every other way of making electricity, solar cells (like the ones on calculators and digital watches) do not work using electricity generators and magnetism. When light falls on a solar cell, the material it is made from (silicon) captures the light's energy and turns it directly into electricity. Potentially, this means solar cells are an extremely efficient way to make electricity. A home with solar electric panels on the roof might be able to make most of its own electricity, for example.

- **Why is it important that people look to alternative energy sources to make electricity?**

Electricity and electronics

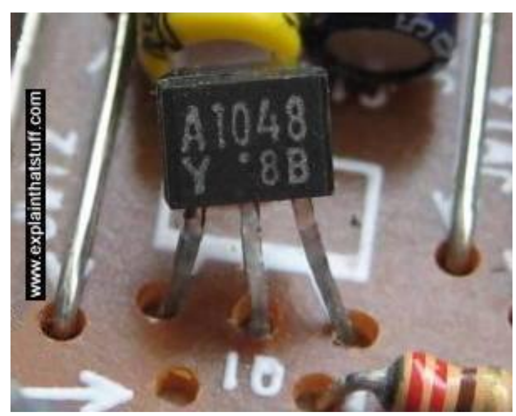

Photo: A transistor (a typical electronic component) on a circuit board. Components like this run on electricity, just like clothes washing machines, but they use much smaller currents and voltages.

Electricity is about using relatively large currents of electrical energy to do useful jobs, like driving a washing machine or powering an electric drill. Electronics is a very different kind of electricity. It's a way of controlling things using incredibly tiny currents of electricity—sometimes even individual electrons! Suppose you have an electronic clothes washing machine. Large currents of electricity come from the power outlet (mains supply) to make the drum rotate and heat the water. Smaller currents of electricity operate the electronic components in the washing machine's programmer unit. These tiny currents control the bigger currents, making the drum rotate back and forth, starting and stopping the water supply, and so on.

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The power of electricity

Before the invention of electricity, people had to make energy wherever and whenever they needed it. Thus, they had to make wood or coal fires to heat their homes or cook food. The invention of electricity changed all that. It meant energy could be made in one place then supplied over long distances to wherever it was needed. People no longer had to worry about making energy for heating or cooking: all they had to do was plug in and switch on—and the energy was there as soon as they wanted it.
Another good thing about electricity is that it's like a common "language" that all modern appliances can "speak." You can run a car using the energy in gasoline, or you can cook food on a barbecue in your garden using charcoal, though you can't run your car on charcoal or cook food with gasoline. But electricity is quite different. You can cook with it, run cars on it, heat your home with it, and charge your cell phone with it. This is the great beauty and the power of electricity: its energy for everyone, everywhere, and always.

• **Explain how your cell phone is powered by electricity. How do electrons light up the screen?**

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Measuring electricity

We can measure electricity in a number of different ways, but a few measurements are particularly important.

Photo: You can use a digital multimeter like this to measure voltage, current, and resistance.

<u>Voltage</u>
The voltage is a kind of electrical force that makes electricity move through a wire and we measure it in volts. The bigger the voltage, the more current will tend to flow. So a 12-volt car battery will generally produce more current than a 1.5-volt flashlight battery.

<u>Current</u>
Voltage does not, itself, go anywhere: it's quite wrong to talk about voltage "flowing through" things. What moves through the wire in a circuit is electrical current: a steady flow of electrons, measured in amperes (or amps).

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Power

Together, voltage and current give you electrical power. The bigger the voltage and the bigger the current, the more electrical power you have. We measure electric power in units called watts. Something that uses 1 watt uses 1 joule of energy each second.

The electric power in a circuit is equal to the voltage × the current (in other words: watts = volts × amps). So if you have a 100-watt (100 W) light and you know your electricity supply is rated as 120 volts (typical household voltage in the United States), the current flowing must be 100/120 = 0.8 amps. If you're in Europe, your household voltage is more likely 230 volts. So if you use the same 100-watt light, the current flowing is 100/230 = 0.4 amps. The light burns just as brightly in both countries and uses the same amount of power in each case; in Europe it uses a higher voltage and lower current; in the States, there's a lower voltage and higher current. (One quick note: 120 volts and 230 volts are the "nominal" or standard household voltages—the voltages you're supposed to have, in theory. In practice, your home might have more or less voltage than this, for all sorts of reasons, but mainly because of how far you are from your local power plant or power supply.)

Energy

Power is a measurement of how much energy you're using each second. To find out the total amount of energy an electric appliance uses, you have to multiply the power it uses per second by the total number of seconds you use it for. The result you get is measured in units of power × time, often converted into a standard unit called the kilowatt hour (kWh). If you used an electric toaster rated at 1000 watts (1 kilowatt) for a whole hour, you'd use 1 kilowatt hour of energy; you'd use the same amount of energy burning a 2000 watt toaster for 0.5 hours or a 100-watt lamp for 10 hours. See how it works?

Electricity meters (like the one shown in the photo above, from my house) show the total number of kilowatt hours of electricity you've used. 1 kilowatt hour is equal to 3.6 million joules (J) of energy (or 3.6 mega joules if you prefer).

You can measure your energy consumption automatically with an energy monitor.

- **Make a chart to Compare & Contrast: Voltage, Resistance & Current**

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A brief history of electricity

- 600 BCE: Greek philosopher Thales of Miletus (c.624–546 BCE) discovered static electricity.
- 1600 CE: English scientist William Gilbert (1544–1603) was the first person to use the word "electricity." He believed electricity was caused by a moving fluid called humor.
- 1733: French scientist Charles du Fay (1698–1739) found that there were two different kinds of static electric charge.
- 1752: American printer, journalist, scientist, and statesman Benjamin Franklin (1706–1790) carried out further experiments and named the two kinds of electric charge "positive" and "negative."
- 1780: Italian biologist Luigi Galvani (1737–1798) touched two pieces of metal to a dead frog's leg and made it jump. This led him to believe electricity is made inside animals' bodies.
- 1785: French scientist Charles Augustin de Coulomb (1736–1806) explored the mysteries of electric fields: the electrically active areas around electric charges.
- 1800: One of Galvani's friends, an Italian physics professor named Alessandro Volta (1745–1827), realized "animal electricity" was made by the metals Galvani had used. After further research, he found out how to make electricity by joining different metals together and invented batteries.
- 1827: German physicist Georg Ohm (1789–1854) found some materials carry electricity better than others and developed the idea of resistance.
- 1820: Danish physicist Hans Christian Oersted (1777–1851) put a compass near an electric cable and discovered that electricity can make magnetism.
- 1821: A French physicist called Andre-Marie Ampère (1775–1836) put two electric cables near to one another, wired them up to a power source, and watched them push one another apart. This showed electricity and magnetism can work together to make a force.
- 1821: Michael Faraday (1791–1867), an English chemist and physicist, developed the first, primitive electric motor.
- 1830s: American physicist Joseph Henry (1797–1879) and British inventor William Sturgeon (1783–1850) independently made the first practical electromagnets and electric motors.
- 1831: Building on his earlier discoveries, Michael Faraday invented the electric generator.
- 1840: Scottish physicist James Prescott Joule (1818–1889) proved that electricity is a kind of energy.
- 1870s: Belgian engineer Zénobe Gramme (1826–1901) made the first large-scale electric generators.
- 1873: James Clerk Maxwell (1831–1879), another British physicist, set out a detailed theory of electromagnetism (how electricity and magnetism work together).
- 1881: The world's first experimental electric power plant opened in Godalming, England.
- 1882: Thomas Edison (1846–1931) built the first large-scale electric power plants in the USA.
- 1890s: Edison's former employee Nikola Tesla (1856–1943) promoted alternating current (AC) electricity, a rival to the direct current (DC) system promoted by Edison. Edison and Tesla battled for supremacy and, although Edison is remembered as the pioneer of electric power, it was Tesla's AC system that ultimately triumphed.

- **DRAW a TIMELINE and place important events that explain the history of the discovery of electricity.**

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DON'T ever play with electricity!

Electricity is amazingly useful—but it can be really dangerous as well. When electricity zaps from power plants to your home, it's at thousands of times higher voltages and massively more dangerous than the electricity in your home. If you are silly enough to touch or play near power equipment, you could die an extremely nasty and unpleasant death—electricity doesn't just shock you, it burns you alive. Heed warnings like this one and stay well away.

Electricity can also be dangerous in your home. Household electric power can kill you, so be sure to treat it with respect too. Don't play with household power sockets or push things into them. Don't take apart electrical appliances, because dangerous voltages can linger inside for a long time after they are switched off. If you want to know what something electrical looks like inside, search on the web—you'll find a safe answer that way.

It's generally okay to use small (1.5 volt) flashlight batteries for your experiments if you want to learn about electricity; they make small and safe voltages and electric currents that will do you no harm. Ask an adult for advice if you're not sure what's safe.

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- Batteries
- Electric motors
- Electronics
- Energy
- Piezoelectricity
- Power plants
- Static electricity

Books

For younger children (ages 9–12)

- Eyewitness: Electronics by Roger Bridgman. Dorling Kindersley, 2007.
- Eyewitness: Electricity by Steve Parker. Dorling Kindersley, 2005.
- Electric Mischief: Battery-Powered Gadgets Kids Can Build by Alan Bartholomew.
- Electricity: Make it Work by Alexandra Parsons. Two-Can, 2000.

For older children (ages 10+)

- Electronic Gadgets for the Evil Genius by Roger Iannini. McGraw-Hill Education, 2013. There are quite a few "Evil Genius" books in this series that will appeal to budding young hackers keen to experiment with more advanced circuits.

Children's books by me

- Cool Science: Experiments with Electricity and Magnetism by Chris Woodford. Gareth Stevens, 2010: A 32-page, hands-on, practical approach to understanding electricity and magnetism.
- Routes of Science: Electricity by Chris Woodford. Facts on File, 2004: Covers the history of electricity, from the ancient Greeks to modern times.

History of electricity

- The Wizard of Menlo Park: How Thomas Alva Edison Invented the Modern World by Randall Stross. Random House, 2007. A revised look at the life of Thomas Edison, which portrays him as a much more flawed and hapless figure than conventional accounts.

Websites

- Electricity Timeline: A brief, interactive chronology of electrical history.
- Exploratorium: Science Snacks: Electricity: Simple experiments with electricity you can try for yourself.
- Energy: Fuelling the Future: A great guide to energy (including electricity) from the Science Museum in London, England. Includes quizzes and other activities.

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