Resisting Current

The collisions between electrons and atoms in a conductor cause resistance to the flow of charge. We measure that resistance in order to determine the effect that it will have on current. Scientists measure resistance in ohms (rhymes with homes). There is a magical little formula used to figure out the resistance in an electrical system. That formula is called Ohm's Law, V=IR.

Measuring Resistance

Less work is possible when resistance is high. The symbol "V" is used to represent something called the potential difference. Potential difference is the amount of work done in moving a charge between two points, divided by the size of the charge. That's kind of complicated, though. You can think of potential as electrical height. High potential (near positive charge) is kind of like being on top of a hill. Low potential (near negative charge) is kind of like being in a valley. So potential difference indicates the difference in electrical height between two points. The greater that difference, the more likely it is that charge will move. The potential difference is measured in volts, and potential is commonly referred to as voltage. "I" is the symbol for current and "R" is the symbol for the resistance of the system. Current is measured in amperes and resistance is measured in ohms.

How can you think of resistance? Have you ever gone to a baseball game? Between innings, we like going to get some food. There are always people between the counter and us. Resistance to current is similar to you trying to make your way through the crowds to get your hot dog. You have to weave your way through the people to reach your goal. The more people in your way, the more resistance. If everyone is in their seats it is super-easy to get your food. There would be very little resistance.

V=IR Let's go back to that equation and look at it in terms of resistance. When you move the values around you get R=V/I. In English that means the resistance of a system is based on voltage and current. Not all conductors follow Ohm's law.

Resistance is also based on the resistivity of a material. The resistivity of a material changes because of chemical makeup or the temperature. Copper is a better conductor than wood so copper would have lower resistivity. That resistivity combines with (1) the distance and (2) the space that charges have to move in (thin vs. thick wires) to affect the "R" value. Greater length results in more resistance, and thick wires result in less. When people connect speakers, they usually use wires that are as short and thick as possible.

Knocking Electrons Around

In metals, electrons carry the charges of the current as it flows. What stops the electrons? What offers the resistance to that current? Nothing allows a perfect flow of current, not even superconductors. In metal, there are tiny flaws. You can't see them because they are on a molecular level. Those imperfections cause the electrons to collide with the metal atoms. When they hit the metal, the electrons lose energy. Where does that energy go? It is usually turned into heat. You can watch a hot plate heat up, or maybe a stove top. They heat up because of the collisions between electrons and the metal. Imperfections mean collisions; collisions mean heat.

Faraday Basics

A changing magnetic field can create an electric current. Faraday's law of induction is one of the important concepts of electricity. It looks at the way changing magnetic fields can cause current to flow in wires. Basically, it is a formula/concept that describes how potential difference (voltage difference) is created and how much is created. It's a huge concept to understand that the changing of a magnetic field can create voltage.

Faraday's Work

Michael Faraday was an English physicist working in the early 1800's. He worked with another scientist named Sir Humphrey Davy. Faraday's big discovery happened in 1831 when he found that when you change a magnetic field, you can create an electric current. He did a lot of other work with electricity such as making generators and experimenting with electrochemistry and electrolysis.

Faraday's experiments started with magnetic fields that stayed the same. That setup did not induce current. It was only when he started to change the magnetic fields that the current and voltage were induced (created). He discovered that the changes in the magnetic field and the size of the field were related to the amount of current created. Scientists also use the term magnetic flux. Magnetic flux is a value that is the strength of the magnetic field multiplied by the surface area of the device.

Faraday's Law

You're going to have to review your Greek letters when you memorize the real formula. Here are the basics...

E=dB/dt

As the magnetic field increases, the voltage created increases. "E" is the value of voltage induced (the old name for voltage was "ElectroMotive Force", or EMF. That's the "E" in the equation). The change in time for the experiment is "dt". Time is measured in seconds. Last is "dB" which stands for the change in magnetic flux. The magnetic flux is the field lines of the magnetic field. The flux is equal to BA, where B is the magnetic field strength, and A is the area. This formula is a bit harder than those you may have seen before.

In English: the amount of voltage created is equal to the change in magnetic flux divided by the change in time. The bigger the change you have in the magnetic field, the greater amount of voltage.

Coulomb Basics

Coulomb's Law is one of the basic ideas of electricity in physics. The law looks at the forces created between two charged objects. As distance increases, the forces and electric fields decrease. This simple idea was converted into a relatively simple formula. The force between the objects can be positive or negative depending on whether the objects are attracted to each other or repelled.

Charges that are closer together create greater forces. Think about a few concepts before you continue reading. Some charges are attracted to each other. Positive and negative charges like to move towards each other. Similar charges such as two positive or two negative push away from each other. You also need to understand that forces between objects become stronger as they move together and weaker as they move apart. You could yell at someone from far away, and they would barely hear you. If you yelled the same amount when you were together, it would be more powerful and loud.

Coulomb's Work

Charles Augustin de Coulomb was a French scientist working in the late 1700's. A little earlier, a British scientist named Henry Cavendish came up with similar ideas. Coulomb received most of the credit for the work on electric forces because Cavendish did not publish all of his work. The world never knew about Cavendish's work until decades after he died.

Coulomb's Law

As charges increase, the forces increase. But you're here to learn about the law. When you have two charged particles, an electric force is created. If you have larger charges, the forces will be larger. If you use those two ideas, and add the fact that charges can attract and repel each other you will understand Coulomb's Law. It's a formula that measures the electrical forces between two objects.

F=kq1q2/r2

"F" is the resulting force between the two charges. The distance between the two charges is "r." The "r" actually stands for "radius of separation" but you just need to know it is a distance. The "q1" and "q2" are values for the amount of charge in each of the particles. Scientists use Coulombs as units to measure charge. The constant of the equation is "k." As you learn more physics, you will see that this formula is very similar to a formula from Newton's work with gravity.

What is a Magnet?

A bar magnet and its field lines. A magnet is an object or a device that gives off an external magnetic field. Basically, it applies a force over a distance on other magnets, electrical currents, beams of charge, circuits, or magnetic materials. Magnetism can even be caused by electrical currents.

While you might think of metal magnets such as the ones you use in class, there are many different types of magnetic materials. Iron (Fe) is an easy material to use. Other elements such as neodymium (Nd) and samarium (Sm) are also used in magnets. Neodymium magnets are some of the strongest on Earth.

Different Types of Magnets

Horseshoe magnet. There are many different types of magnets. Permanent magnets never lose their magnetism. There are materials in the world that are called ferromagnetic. Those materials are able to create and hold a specific alignment of their atoms. Since many atoms have a magnetic moment (tiny magnetic field), all of the moments can add up to create a magnet. Scientists use the word hysteresis to describe the way the atoms stay aligned.

Most of the magnets you see around you are man-made. Since they weren't originally magnetic, they lose their magnetic characteristics over time. Dropping them, for example, weakens their magnetism; as does heating them, or hammering on them, etc.

There are also air-core magnets. Air-core magnets are created by current flowing through a wire. That current produces the magnetic field. You create an air-core magnet by wrapping miles of wire around in a doughnut shape (toroid). When you send current through the wire, a magnetic field is created inside of the doughnut. Scientists sometimes use air-core magnets to study fusion reactions.

Electromagnets are different because they have a ferromagnetic material (usually iron or steel) located inside of the coils of wire. The core isn't air, it is something that aids in producing magnetic effects, so electromagnets are typically stronger than a comparable air-core magnet. Air-core and electromagnets can be turned on and off. They both depend on currents of electricity to give them magnetic characteristics. Not only can they be turned on and off, but they can also be made much stronger than ordinary magnets. You might see an electromagnet at work in a junkyard lifting old cars off the ground.

A Direct Current

Direct current flows in one direction. There are two main types of current in our world. One is direct current (DC) which is a constant stream of charges in one direction. The other is alternating current (AC) that is a stream of charges that reverses direction. Let's look at DC power which was refined by Thomas Edison in the 1800s.

Moving in One Direction

The current in DC circuits is moving in a constant direction. The amount of current can change, but it will always flow from one point to another. Before we move on, we need to explain that physicists, as well as electricians, refer to something called conventional current.

Do you remember that we talked about physicists agreeing to always use positive charges to determine how electric field lines would be drawn? Following through on that agreement, they also agreed to explain charge flow in terms of positive charges rather than electrons. So although electrons would flow from negative to positive, by convention (agreement), physicists refer to conventional current as a flow from high potential/voltage (positive) to low potential/voltage (negative). Reminding you that potential is like electrical height, this means that conventional current flows "downhill", which makes sense.

Current moves in the opposite direction of charged particles. Electrons move from areas where there are excess of negative charges to areas where there are a deficiency (or positive charge). Electrons move from "-" to "+", but conventional current is considered to move in the other direction. When you set up a circuit, conventional current is considered to move from the "+" to the "-" side.

The idea about using positive charges in forming explanations comes from Benjamin Franklin. In Franklin's day, we didn't know about protons and electrons. Franklin believed that something moved through electrical wires, and he called these things "charge". He assumed there was only one kind of charge, and he logically assumed that charge would flow from a spot that had an excess (extra), to a spot that had a deficiency (too few). He called the spot with an excess "positive" and the spot with a deficiency "negative". So, for Franklin, charge flowed from positive to negative. We simply honor his achievements by continuing with this idea.

Battery Basics

Batteries are a great example of a direct current power source. The best real-life example of direct current is a battery. Batteries have positive (+) and negative (-) terminals. If you take a wire and connect the positive and negative terminals on a battery, the electrons in the wires will begin to flow to produce a current. You can prove that the current is flowing if you connect a small light to the circuit. The light will begin to glow as the electrons pass through the filaments.

DC power is used all over the world. You will probably use direct current power whenever you carry something around that uses electricity. Everything that uses batteries runs on DC power. Other countries use more portable power supplies because they might not have electric wiring in their houses.

That electric wiring in your house is AC power and it is completely different than DC. There are machines that can convert DC to AC power. Those machines might be used to take a DC battery in a boat and convert the power to AC so that a refrigerator can use it.

An Alternating Current

Alternating current switches direction while direct current only moves in one direction. There are two main types of current in our world. One is direct current (DC), which is a constant stream of electrons in one direction. The other is alternating current, which is a stream of charges that reverses direction. Scientists such as Charles Proteus Steinmetz and Nikola Tesla made great advances when AC power was just a science experiment.

Flowing Back and Forth

Charges (electrons) must always be flowing to have a current. However, the flow of charges does not always have to be in one direction. In alternating current, the charges move in one direction for a very short time, and then they reverse direction. This happens over and over again.

Low frequency and high frequency wavelengths. Scientists describe the cycle of switching directions as the frequency. Frequency is measured in Hertz (Hz). Currents that cycle more often during a specific amount of time are said to have a higher frequency. AC power cycles 60 times per second in the US.

Since the web is a global resource, we should also mention that there are different alternating current frequencies across the world. While we all use alternating current, the switching happens different amounts during a specific time period. Most countries use AC frequencies at either 50 hertz or 60 hertz.

Cheaper and Stronger

High-tension powerlines carry power to cities all over the world. Why do we use AC power all over the world? It's cheaper and easier to make devices for AC power. It is less expensive because you can increase and decrease the current for AC power very easily. The power switches for AC power are also less expensive to manufacture. Probably the biggest advantage of AC is that you can use high voltages with small currents to reduce losses when you transmit power. Remember that lost energy increases the more collisions you have, and reducing current decreases the amount of collisions (and reduces heating in the wires). You can send power with DC, but the DC power transmission loses a lot of energy. You would have to put much more effort into sending DC power over the same distance.

Alternating Around You

BIG NOTE: NEVER touch the outlets in your house. You will get electrocuted. There is more to electricity than voltage. It's the current that will kill you.

The easiest place to see AC power in action is in your house. All of the appliances and lights in your house probably run off of AC power. There are also power converters that change DC power into AC power when you need electricity and there are no plugs around (like camping).