Electricity

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Overview

Electricity is all about moving really tiny stuff, really fast. It is contained in almost everything all the time. Computers, lights, cell phones, and even our own cells, are all charged with electricity at this very moment. Excited? Don't get too amped up just yet! There is a lot to know about this stuff, and it just keeps getting more interesting.

The Atom

Atoms are the building block of the universe. Everything is made of them, everything uses them, and everything would disappear without them. What is an atom made of? Electrons, protons, and neutrons - really tiny stuff - connected together with magnetism and electric fields, in a volume of space.

But before this turns into a description of matter, let's stop and focus on the parts of atoms that are relevant to electricity. For more info on atoms and subatomic particles, check out Wikipedia - "atom". The component that relates to electricity is the electron, the charged particle that helps define the material the atom is part of.

Depending on how many electrons there are in an atom, how densely packed they are, and how free they are to move around, an atom and the material it makes can be hard or soft, flexible or rigid, and conductive or nonconductive (conductivity is the measure of whether or not electricity will travel through the material). Let's look at what makes a material more conductive at the atomic level.

Conductivity

Conductivity is the measure of how easily electricity moves through a material. Materials like copper, gold, and iron easily allow electricity to pass through. Materials like wood, glass, and plastic do not. Why is this? It is all about freedom of movement of electrons. From the human perspective, a grey piece of plastic is not all that different from a piece of aluminum. Both are hard, can be dented, can bend a little then break, can be shiny or not, and can come in any shape or size. Why is it that the aluminum is a good conductor, but the plastic is not? You have to look at it from an atomic level to understand this.

Electrons in plastic are stuck in place and have no ability to move around, and the electrons of the metal can move around freely. This is the fundamental difference between something that will carry electricity, and something that won't. It works a lot like dominoes. What will happen if 1,000 dominoes were lined up on end, back to back, with no space in between (analogous to the plastic) and then the first domino in line is tapped? Nothing. The dominoes are not free to move and they just stand there as though nothing happened. If they were lined up again on end, leaving an inch or so between each domino (analogous to the aluminum) and were tapped, they would fall down, one after another, until the last domino has fallen over at the end of the line.

This is exactly how electricity works. Electricity happens when a force moves the first electron on a surface where electrons are free to move. This moving electron bumps into the next electron, and so on until the last free electron moves. Since the electrons can't fall over, they are instantly ready to repeat this process. If the last electron happens to come in contact with the initial pushing force, the cycle continues until there is no energy left.

Voltage, Current, and Tabletop Games

Current and voltage are the primary descriptors of an electric circuit.

Voltage is similar to a pump; it creates an electrical "pressure" that can apply a force on electrons. In the domino example, voltage is the initial force that pushes the first domino over, starting the chain reaction. Imagine if the domino chain were to have one part that went up a hill. As each domino falls over going up the hill, they will slow down since it takes extra work to go up hill (just like a car will slow down when going up a hill). If the hill is large, or the speed and force of the domino is low, there may not be enough power to push all of the dominoes over. Another force will have to be exerted at the place the dominoes stopped falling over or the dominoes will have be be lined up and re-started with a stronger initial force.

This is just like voltage. If electricity was being sent from one side of a battery to the other, there will always be enough energy regardless of the voltage to do this. However, if a hill (a power consuming device such as a light) is placed in the path of the electricity, a strong enough initial push will be needed to ensure that the energy can make it up the hill.

The other aspect of dominoes that can be observed and controlled is how many dominoes fall over in a given amount of time. One column of dominoes will fall over at about the same rate, because of how gravity works, no matter how hard the initial push is. If the desire is for more dominoes to fall over in the same amount of time, additional parallel columns of dominoes will be needed.

This is analogous to current. Current is a measure of how many electrons pass through a cross section of a material in a second, where one amp is equal to 6.24×10^{18} (624 followed by sixteen zeros) electrons per second. That's a lot of electrons.

Electric Circuits

Electric circuits are the exploitation of the way current and voltage work. More voltage will push higher up an electrical hill, and more current will send more energy through a wire. A switch works like removing a domino from the path, and a motor or a light is equivalent to the electrical hill.
The basic rule of electric circuits is that energy that leaves a power source (i.e., a battery) must return. This is why batteries and plugs have two terminals (one positive and one negative). If the positive and negative terminals of a battery or other power source are connected, a circuit has been made. The circuit can be used to engage electrical devices as negative connects to positive, and vice versa. If a lamp is installed in the circuit, assuming there is the correct amount of voltage, the lamp

will glow yellow. If you install a motor with the correct voltage, it will spin. Want to control when it spins? Add a switch. The switch connects and disconnects power as the toggle switch is flipped from on to off.

How does electricity make a light glow and a motor spin?

Moving electrons have energy (as does any moving mass) as indicated by Einstein's law, $E=MC^2$. Since an electron has a mass (M) of $9.10x10^{-31}$ (a decimal point followed by thirty zeros followed by 91) and the speed of light (C) is 299,792,458 meters per second, the energy of an electron is $8.18x10^{-14}$ (a decimal point with thirteen zeros followed by 818) joules.

A joule is a measure of how much energy something has or needs. A 100-watt lamp, for example, requires 100 joules of energy every second. And since the amount of energy in an electron is known (E), we know we need to provide $1.22x10^{15}$ electrons per second. Again, that's a lot of electrons.

The Rules of Electricity

Like everything else in life, electricity has rules that it must follow in order to work. These rules are:

- The laws of parallel and series voltages and currents
- Electricity must create a complete circuit to work and will dissipate all of the voltage by the end, but none of the current

The first rule, parallel and series voltages and currents, describes how electricity travels based on the shape of its path. Suppose electricity travels down a wire, splits into two wires, and becomes one wire again. Also suppose there are similar light bulbs installed on each leg of the split. Each bulb will receive the same voltage as was applied to the single wire before the wire split, but only half of the current available.

If one wire does not split, but still contains two light bulbs in a row, each light bulb will receive the same amount of current, but only half of the voltage.

The rule of the completed circuit is that at the end of a circuit, there is always the same exact amount of current flowing as there was at the beginning; however, the voltage drops to zero as it has been dissipated as electrical energy in the form of light, motion, or heat. That is why a wire heats up if you connect it between the positive and negative side of a battery with no other load. The voltage must be zero at the end of the circuit, and heat is the only load available to dissipate the energy.

Useful Equations

Voltage = Current X Resistance (**$V = I * R$**)
Power = Current X Voltage (**$P = I * V$**)
Therefore,
Power = Current^2 X Resistance (**$P = I^2 * R$**)
Energy = Mass X [Speed of light]^2 (**$E = M * C^2$**)
Power = Energy / Time (**$P = E / T$**)
1 Watt of Power = 1 Joule/Second