Everything you need to know about electricity (for now.)

Longer (17 min.) video intro to electricity is here:
https://youtu.be/0MBnxzCzwMs

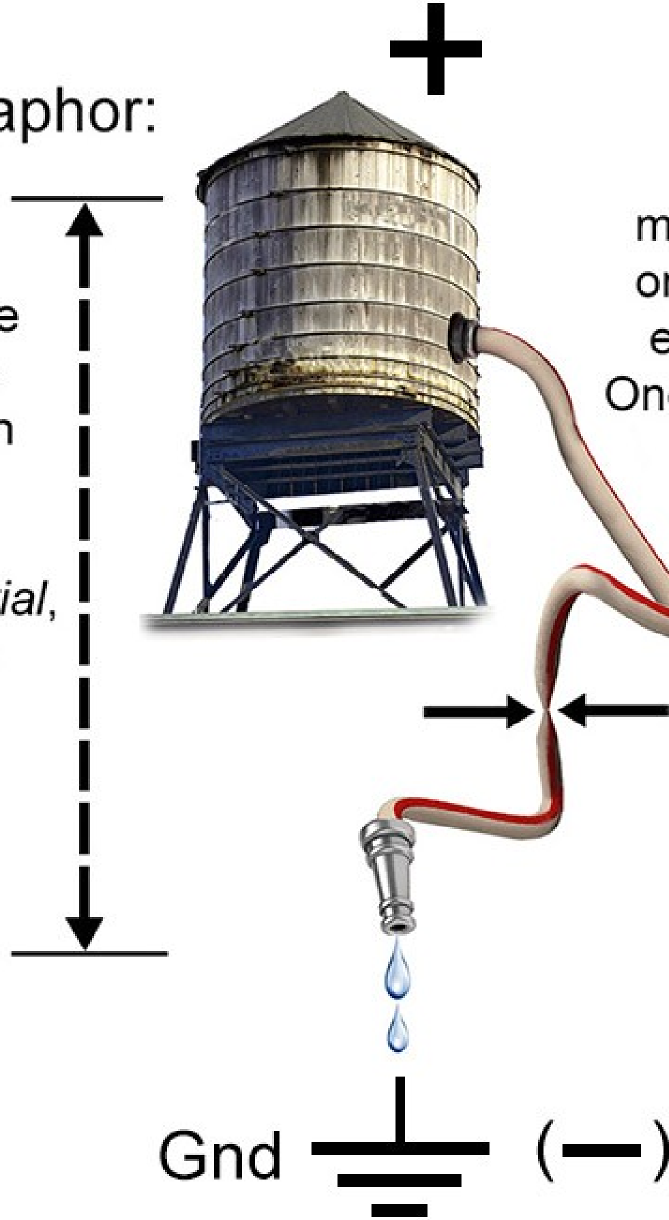
SP26 Electronic Projects II

Electricity is the movement of electrical charge through a circuit (usually, flowing electrons.)

The Greek word for “amber” is “elektron”

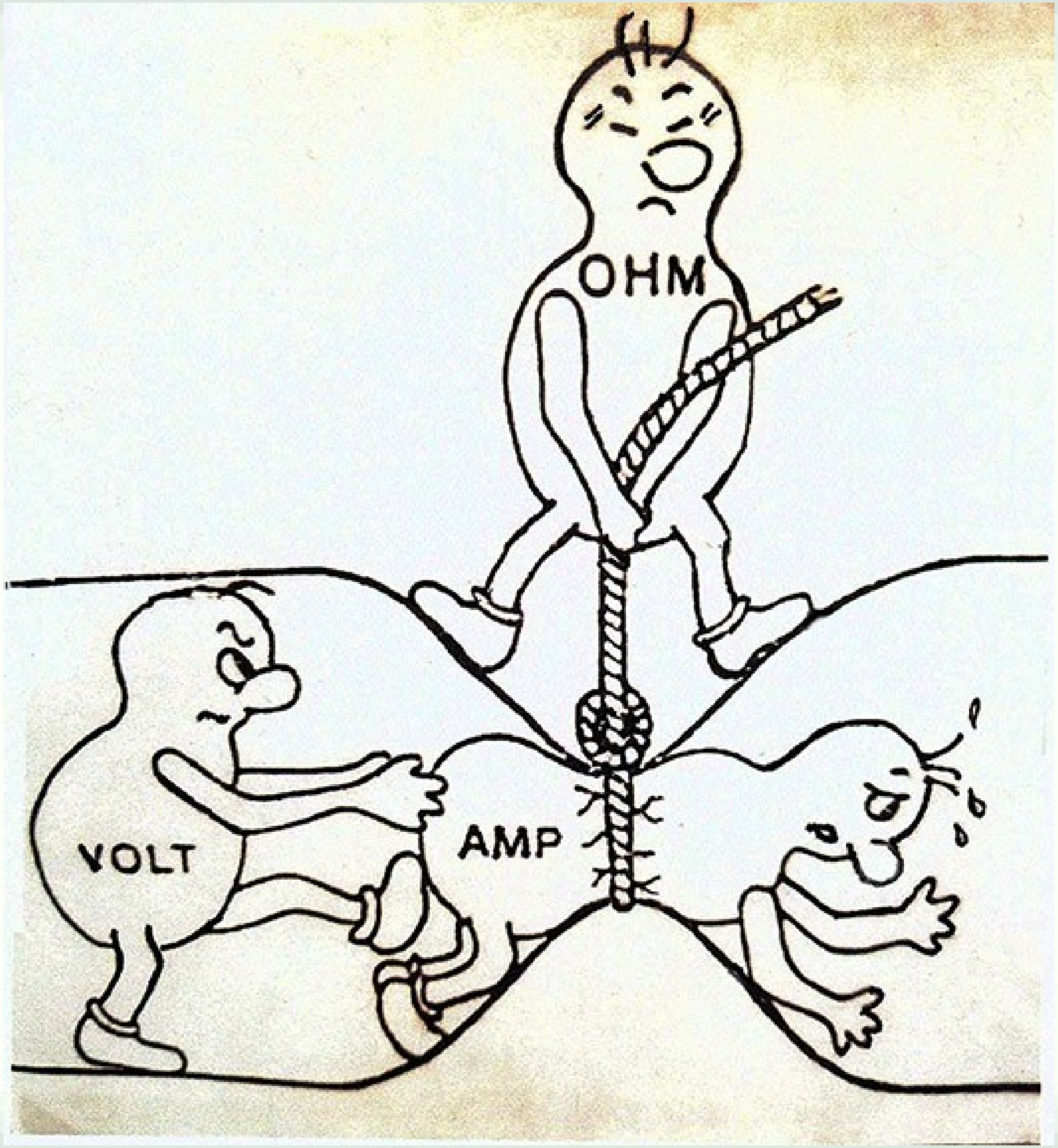
The water metaphor:

The water pressure (measured as the difference between two points) is a metaphore for *electromotive potential*, measured in units called **volts**.

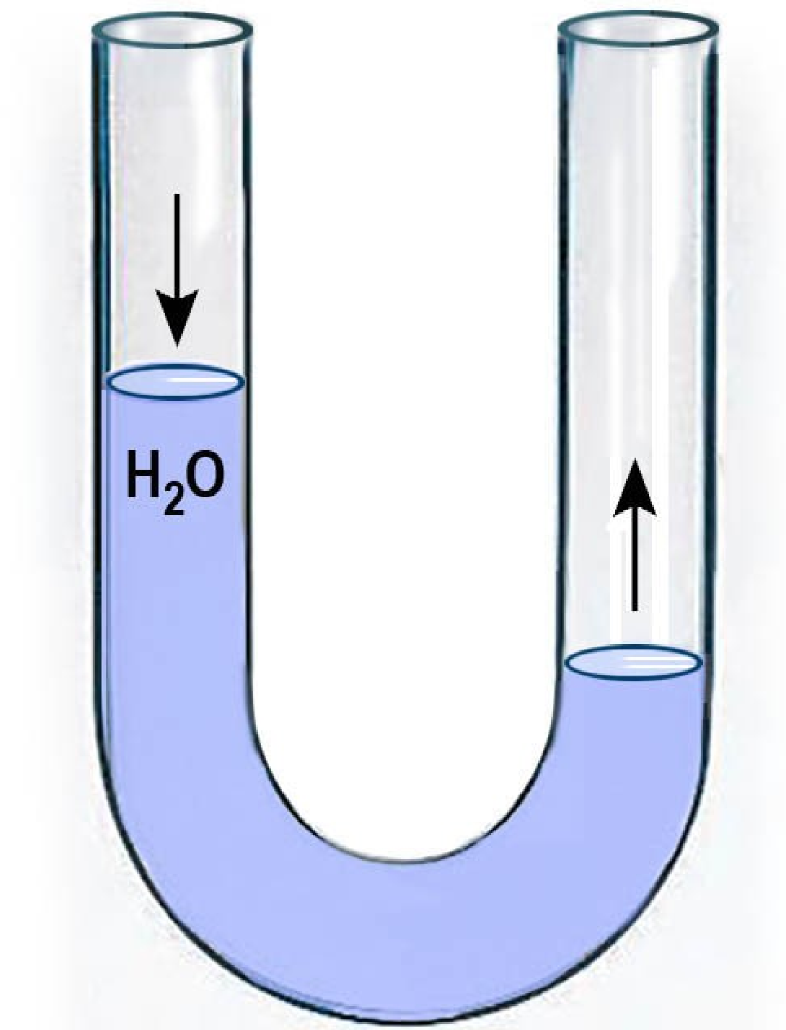


The volume of water flowing is a metaphor for current, measured in units called **amperes** or simply **amps**. A unit measure of electrical charge is the coulomb. One amp = one coulomb per second.

Electrical components called “resistors” slow down the amount of current flowing in a circuit. The property of *impedance* (resistance) is measured in units called **ohms**. In the metaphor, it’s represented by pinching the diameterof the pipe.


OHM
VOLT
AMP

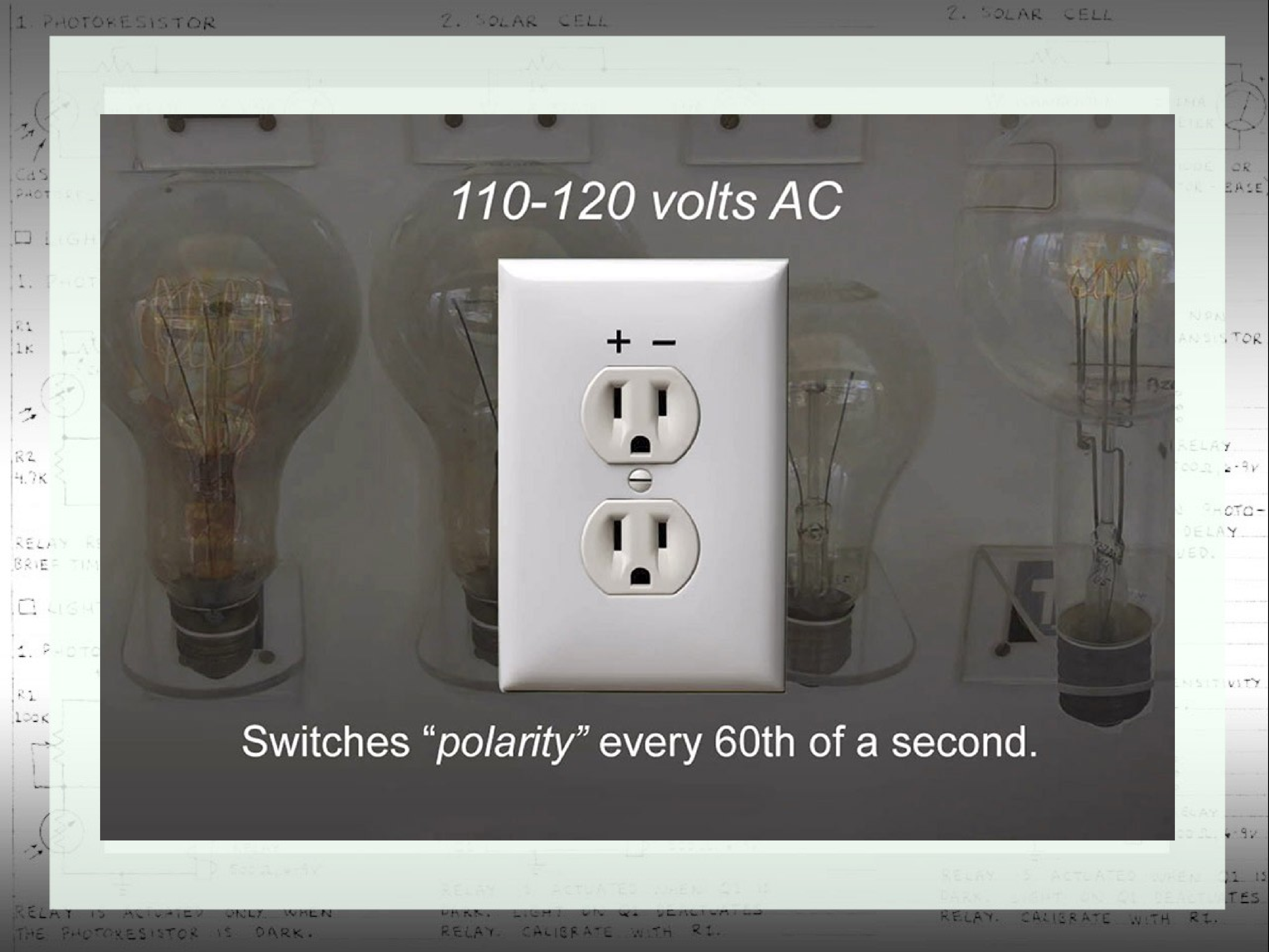
“Volts” is a unit of measure of the difference in *electrical potential* between 2 points in a circuit.



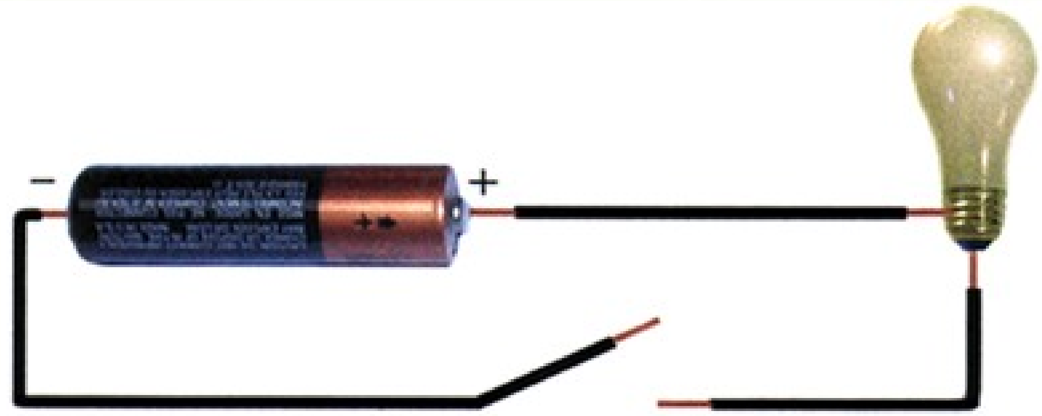
Metaphorical example showing “kinetic potential”...

110-120 volts AC

Switches “*polarity*” every 60th of a second.

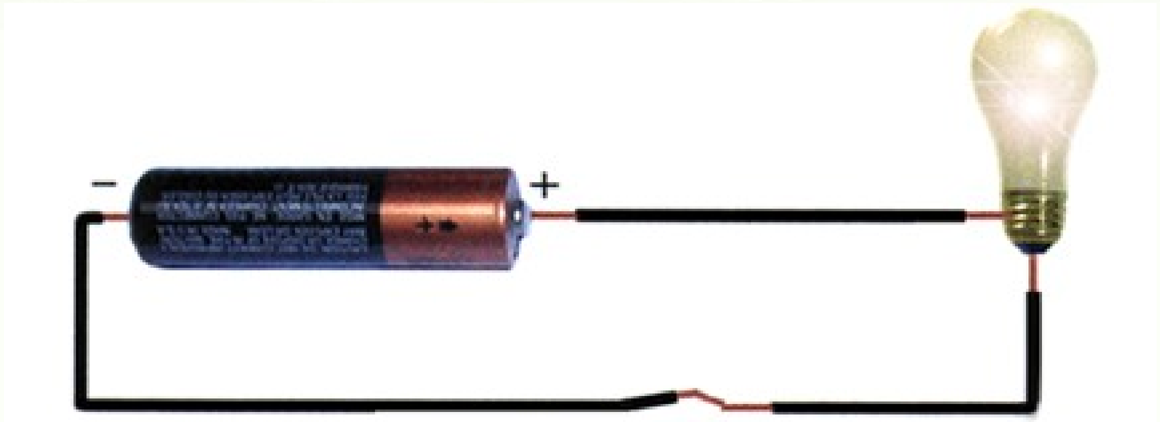

110-120 volts AC
+ –
Switches "*polarity*" every 60th of a second.

Simple DC Circuits (open):



Here is perhaps the simplest circuit we could build. In this case the light bulb is the “load” in the circuit, controlled by a “single pole, single throw” (SPST) switch. (More about switches later.)

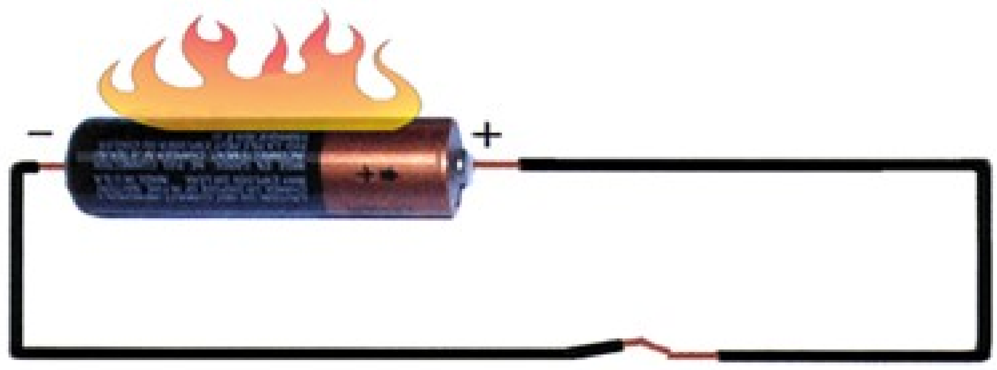
Simple DC Circuits: (closed)



Electricity flows from a source, where there is the greatest concentration of electrons (positive pole) to the place with a relatively lower concentration of electrons (negative pole, often also referred to as "ground") through the path of least resistance.

DC (Direct Current) circuits harness the power of the electrical current flowing from a positive source, energizing a load of some kind as it passes through it to ground.

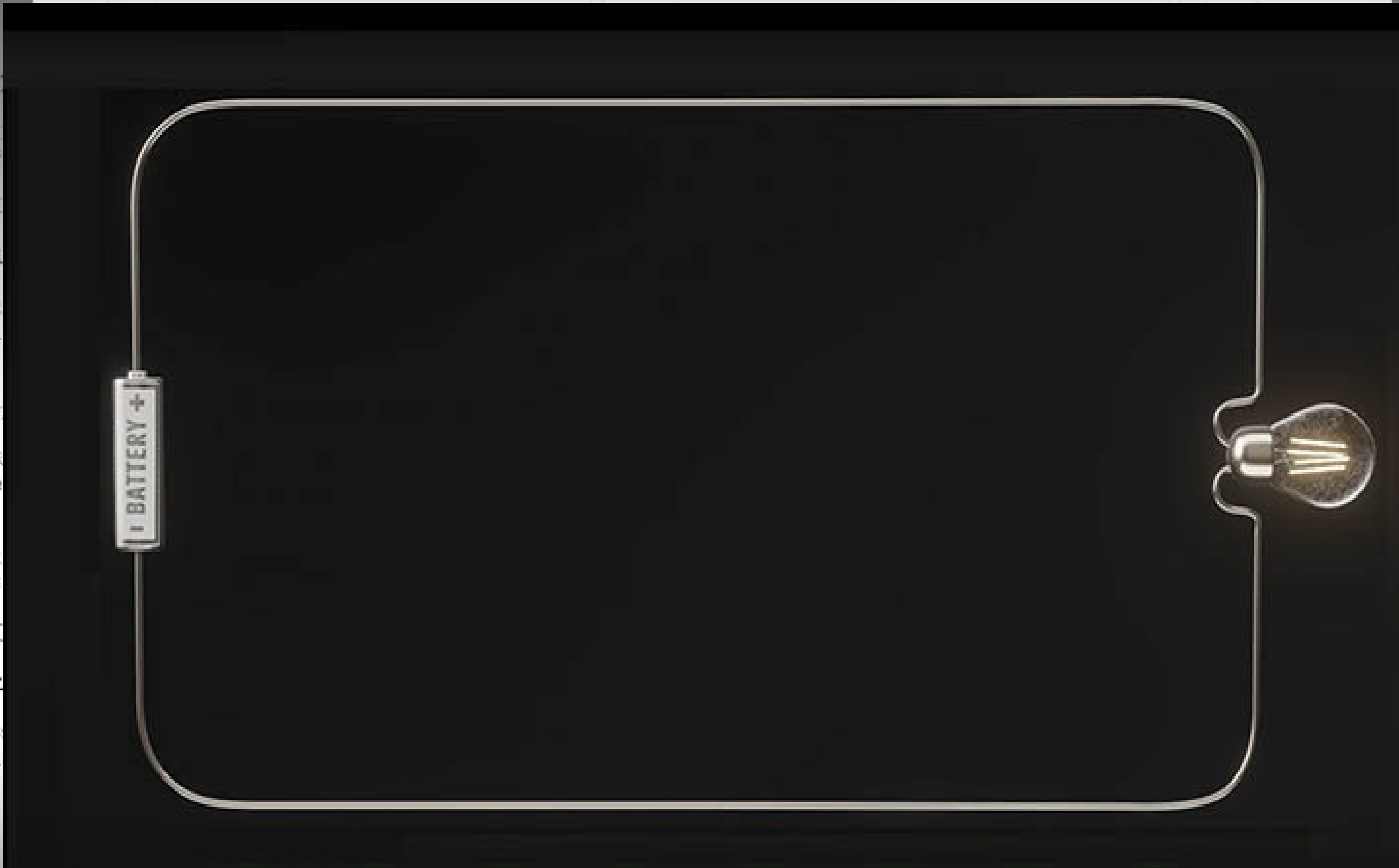
Simple DC Circuits: (short!)



- Always make sure there is a load of some kind on the circuit. A path through a conductor directly from source to ground is called a ***short circuit*** (very bad.) It will cause the power source to over-heat and die. In this case it would cause the battery to get very hot and die. If this happens with AC current in your home it can cause catastrophic fires.

Materials that have lots of “free electrons” in their atomic structure that move easily from and between their valence shells are referred to as **conductors** (e.g. copper, gold.) Conversely, materials with relatively few free electrons are called **insulators** (e.g. wood, rubber.) If the electromotive potential is great enough, just about anything can become a conductor, even the air in the sky (in the case of lightning.)

Electrons don't have to travel the entire length of a circuit in order for electrical conductance to happen.



"Energy Doesn't Flow through Wires": https://www.youtube.com/watch?v=bHIhgxav9LY

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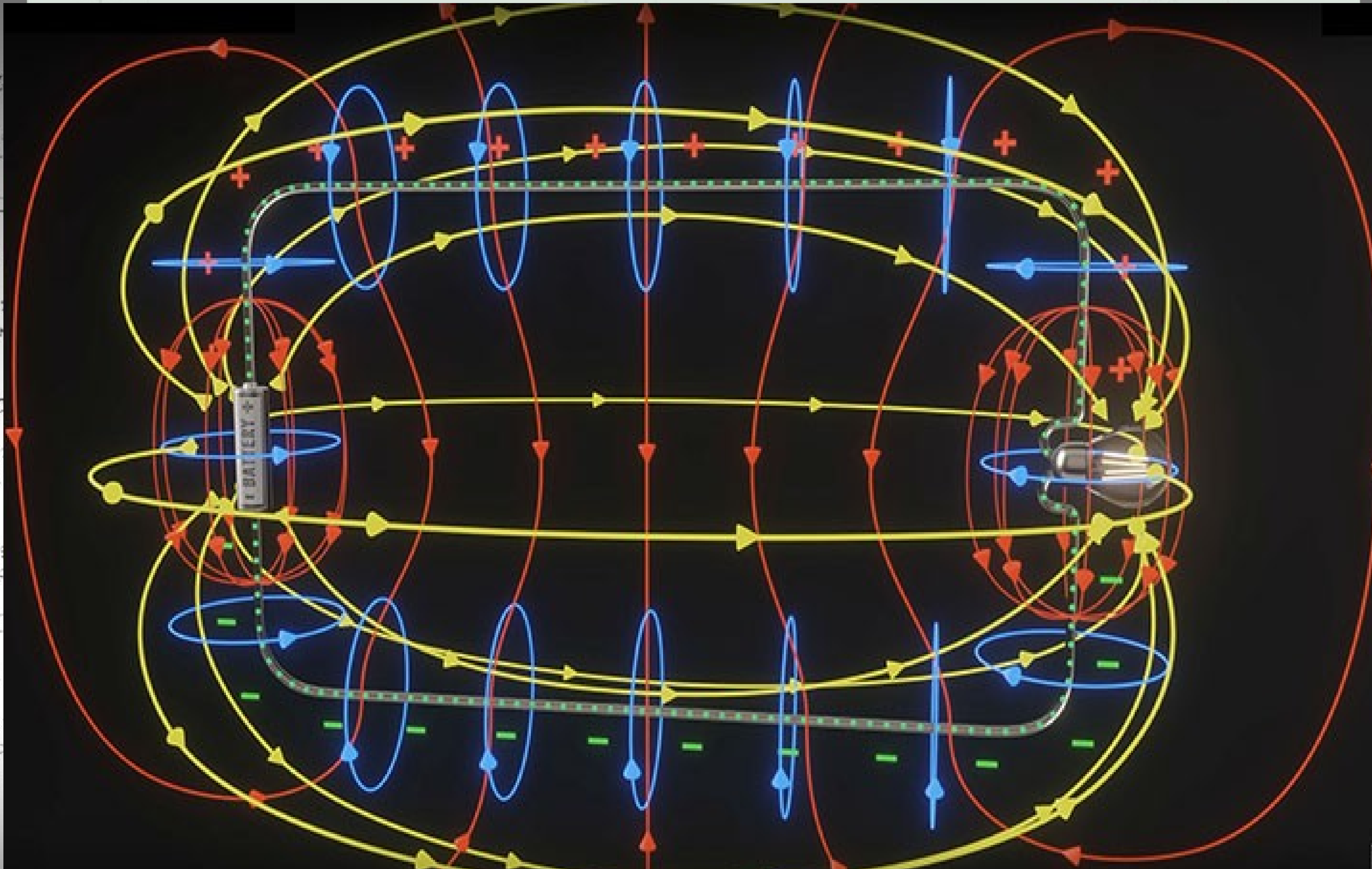
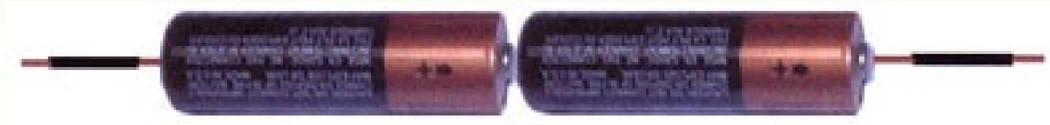


“Energy Doesn’t Flow through Wires”: https://www.youtube.com/watch?v=bHIhgxav9LY

Series and Parallel:



Batteries in series.

When connected “in series”, DC voltage sources are added. In the above example, two AA batteries (1.5 volts each) wired in series supply 3 volts to the circuit. (1.5 + 1.5 = 3.)

Batteries in parallel.

When connected “in parallel”, batteries' voltages are unaffected, but the current (measured in *amperes*) is increased. In the above example, two AA batteries (1.5 volts each) wired in parallel supply 1.5 volts to the circuit, but can do so for a longer time than a single battery alone.

What's going on inside a resistor?

If you break one open, and scratch off the outer coating of insulating paint, you might see an insulating ceramic rod running through the middle with copper wire wrapped around the outside. A resistor like this is described as wire-wound. The number of copper turns controls the resistance very precisely: the more copper turns, and the thinner the copper, the higher the resistance.

In smaller-value resistors, designed for lower-power circuits, the copper winding is replaced by a spiral pattern of carbon. Resistors like this are much cheaper to make and are called carbon-film. Generally, wire-wound resistors are more precise and more stable at higher operating temperatures.

Resistor Color Codes

Resistance values:

- 0 = Black
- 1 = Brown
- 2 = Red
- 3 = Orange
- 4 = Yellow
- 5 = Green
- 6 = Blue
- 7 = Violet
- 8 = Grey
- 9 = White

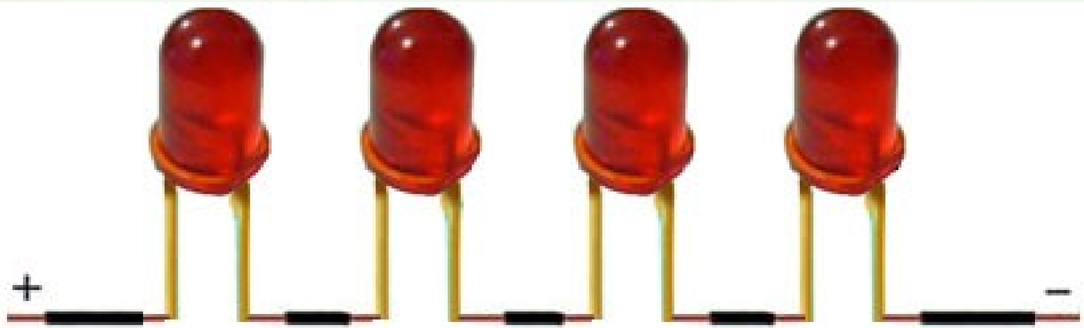
Tolerance values

- Brown ± 1%
- Red ±2%
- Gold ±5%
- Silver ± 10%

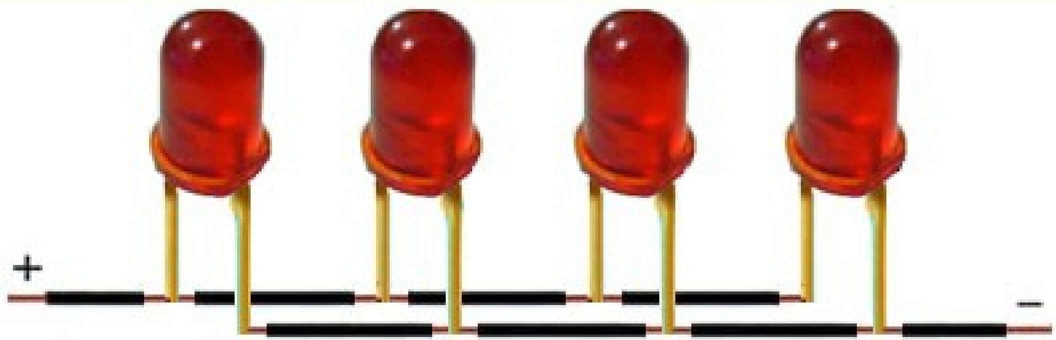
On most resistors, you'll see there are three rainbow-colored bands, then a fourth band usually colored gold, or silver.

The first two of the rainbow bands tell you the first two digits of the resistance. Suppose you have a resistor like the one shown here, with colored bands that are brown, black, and red and a fourth golden band. You can see from the color chart below that brown means 1 and black means 0, so the resistance is going to start with "10". The third band is a decimal multiplier: (how many zeros to add on the end.) Red means 2, so we multiply the 10 we've got already by 10 × 10 = 100 and get 1000. Our resistor is 1000 ohms.

Series and Parallel load:



series circuit



parallel circuit

The concept of being “in series” or “parallel” also applies to electrical components which are wired as the load of the circuit.

Some Definitions:

– The name for the property of having a “positive” and “negative” polar orientation is called “**polarity**.” Magnetic polarity and electrical polarity are inextricably linked.

- When a magnetic field is moved through a coil of wire, it causes electrons to move through the wire (electricity) in a process called “**induction**.” The moving magnetic field “induces” electrical current.

- **Direct Current** (**DC**) occurs when electrons flow in one direction continuously along a conductor. This is the kind of current obtained from batteries and is generally safe to work with at low voltages, and is the main kind of current we will be working with in our circuit constructions.

- **Alternating Current**(**AC**) occurs when the direction or polarity of the current alternates direction. AC is better suited for transmission through long distance power lines. Household (wall plug) current in North America delivers 110-115 volts, alternating at 60 times a second (60 Hz). A wire carrying AC will induce a current in nearby wire.

- “Wall current” (110-120 VAC) is a dangerous, potentially life-threatening energy source. <u>**Do not use it**</u> in the circuits you build without the advice and oversight of faculty and staff who can assure the work is done safely.

Some Definitions:

– Electricity (electrons flowing through a circuit) has two principle properties: voltage and current.

- **Electromotive potential** *(symbol: V, or sometimes the more archaic E)* is the difference in potential energy between two points in a circuit. It is measured in units called ***volts*** (after Alessandro Volta, inventor of the battery.) In the metaphor of water and plumbing often used to visualize electrical charge flowing in a circuit, voltage would be thought of as water pressure.

- **Current**: *(symbol: I for "intensité")* Current is the rate of flow, or volume of electrical charge through a circuit. The unit of measure is the ***ampere***, usually shortened to "***amp***" (after French physicist André-Marie Ampère.) It's a measure of how many electrons go past a given point in a circuit per second. (In the water metaphor, current can be thought of as the diameter of the pipe.)

- **Power** *(symbol: W)* Volts and amps multiplied together equals the total amount of electrical power in the circuit, measured in units called ***watts*** (after James Watt, Scottish inventor and engineer.)

- **Resistance** *(symbol: Ω -Greek letter for omega)* Also called **impedance**, is measured in units called ***ohms*** (after German physicist, Georg Ohm.)

Prefixes:

These prefixes are universally used to scale units in science and engineering:

Prefix	*Abbreviation*	*Multiplier*
tera	T	10^{12} (= 1,000,000,000,000)
giga	G	10^{9} (= 1,000,000,000)
mega	M	10^{6} (= 1,000,000)
kilo	k	10^{3} (= 1,000)
(none)	*(none)*	10^{0} (= 1)
centi	c	10^{-2} (= 0.01)
milli	m	10^{-3} (= 0.001)
micro	µ	10^{-6} (= 0.000 001)
nano	n	10^{-9} (= 0.000 000 001)
pico	p	10^{-12} (= 0.000 000 000 001)
femto	f	10^{-15} (= 0.000000000000001)

When abbreviating a unit with a prefix, the symbol for the unit follows the prefix without space. Be careful about upper-case and lower-case letters (especially m and M.) 1mW is a milliwatt, or one-thousandth of a watt, but 1MW is a megawatt (one million watts.) The unit name is only capitalized when it is abbreviated. For example, in describing cycles-per-second we use hertz and kilohertz, but Hz and kHz.