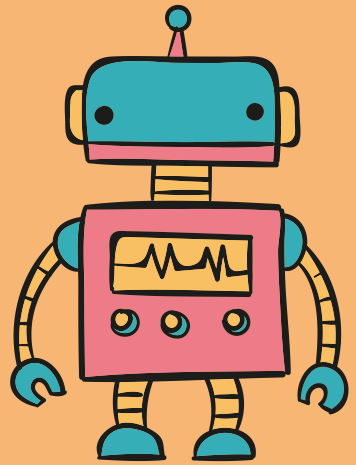
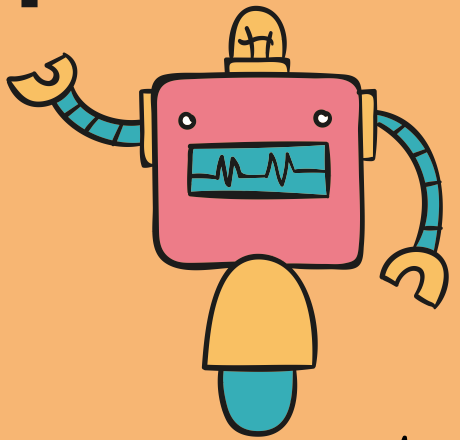
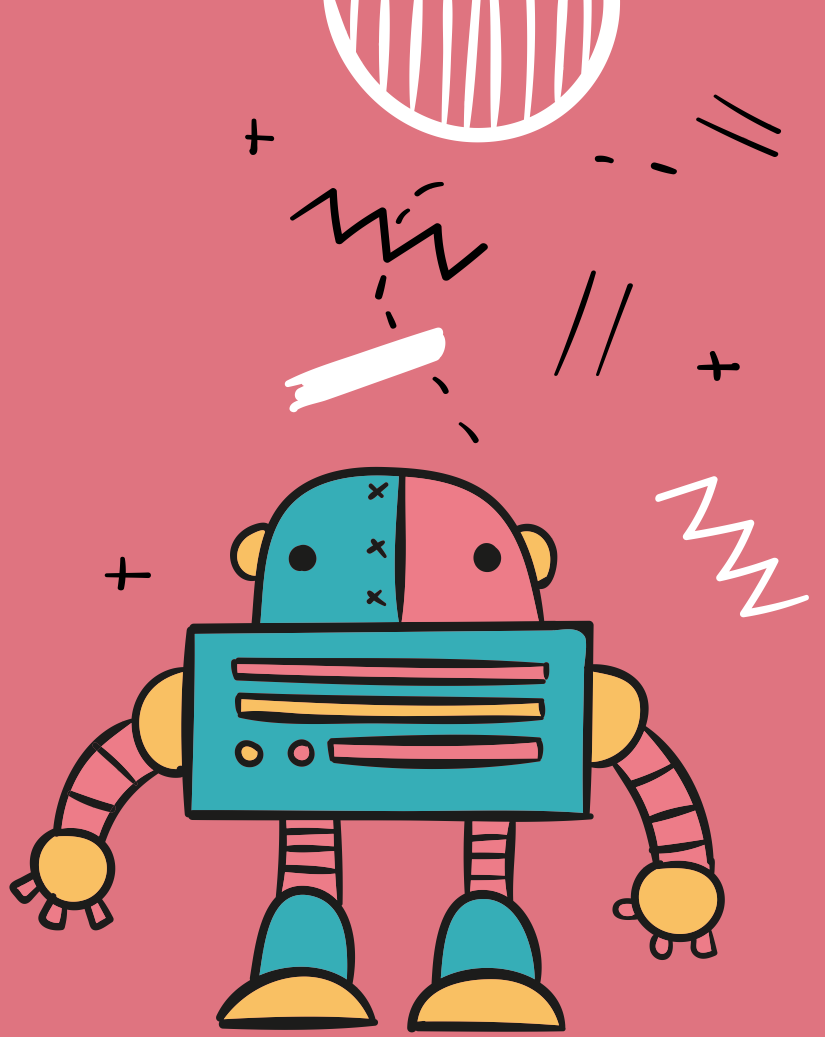
Electronics: from analog to digital

Gabriel Pedroza and Raphael Correia

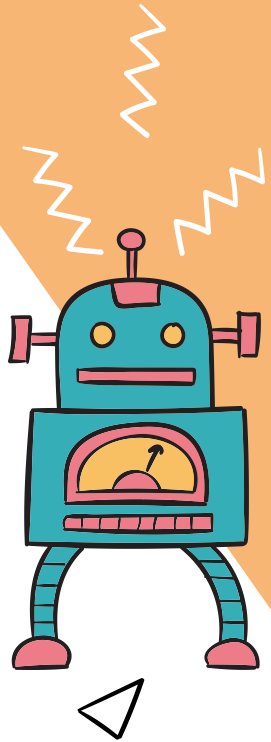


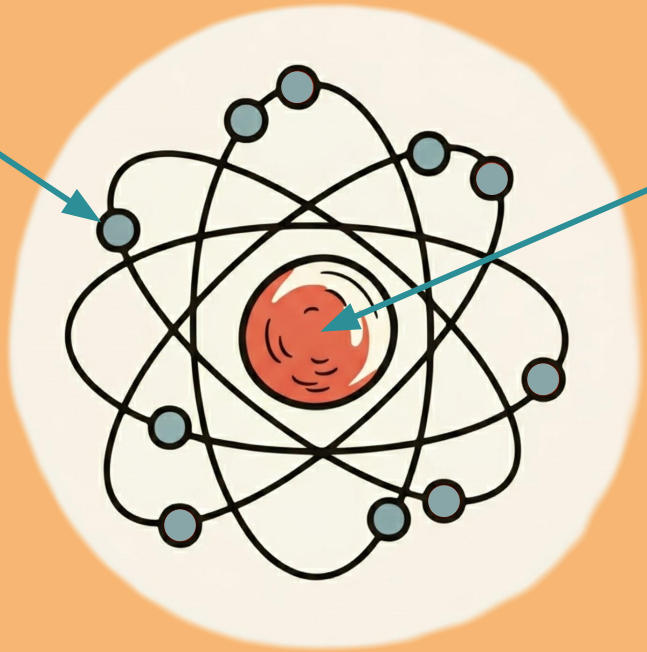


Electrostatics

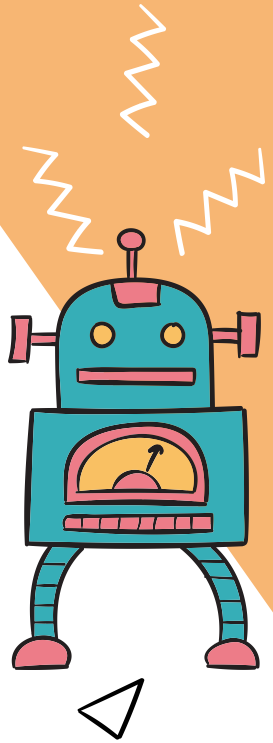


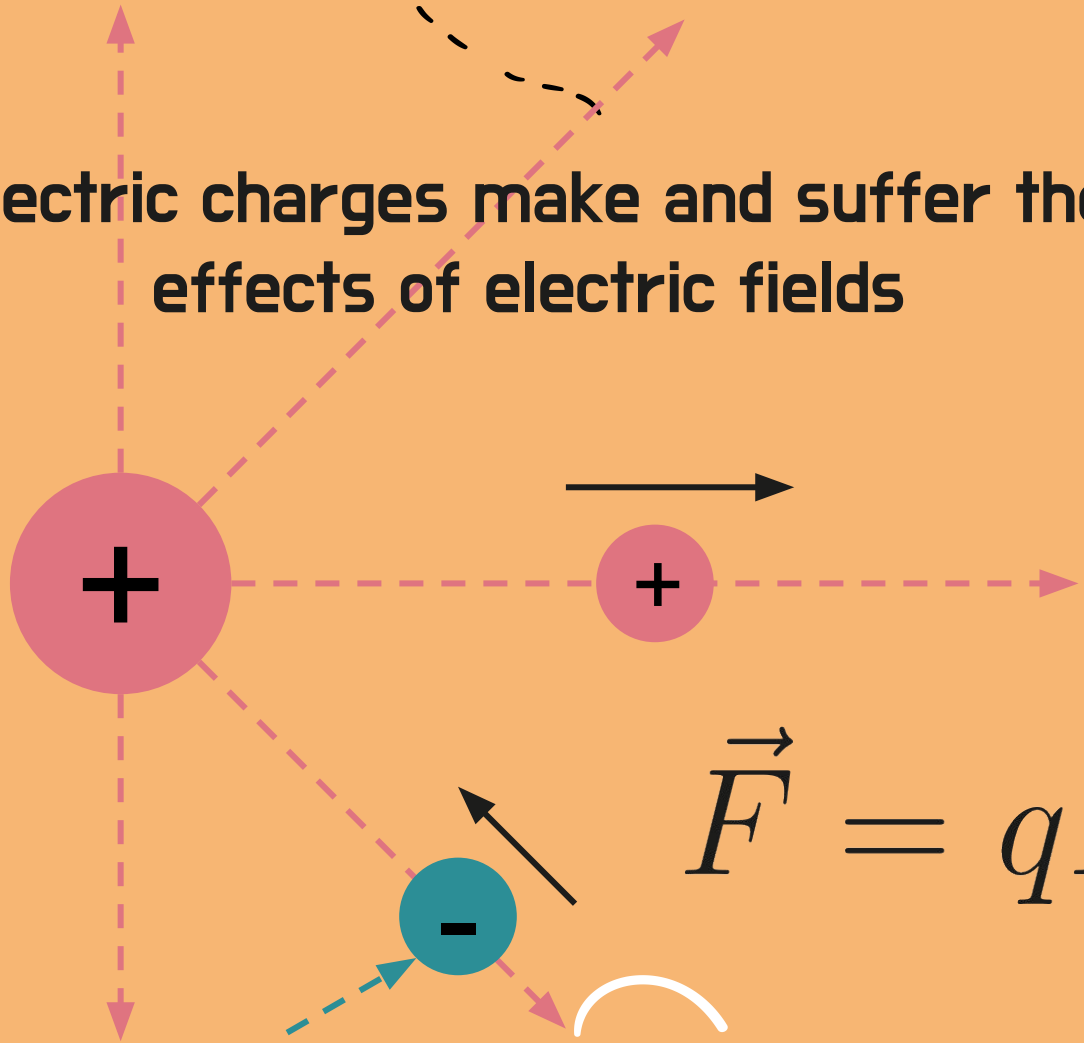
Electric charge: a fundamental property





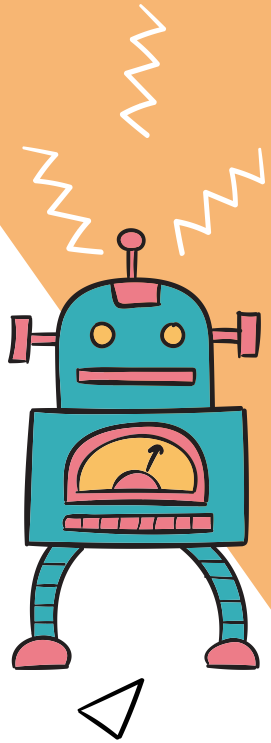
Electric charges make and suffer the effects of electric fields

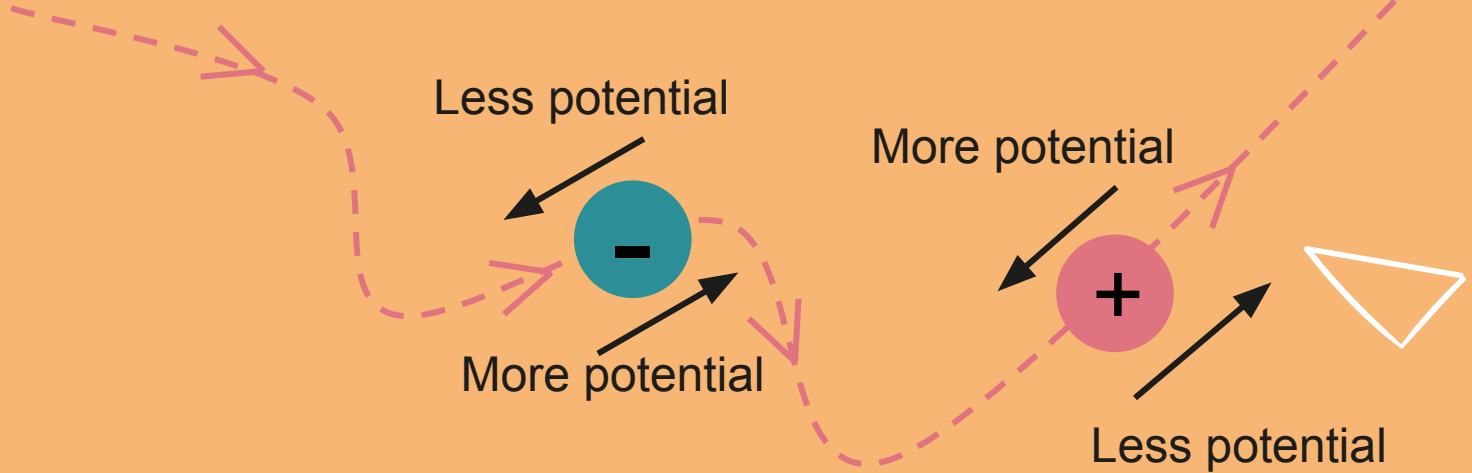




$$\vec{F} = q\vec{E}$$

Walking along field lines changes potential energy



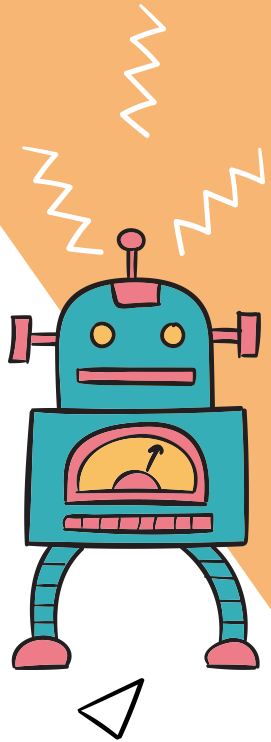


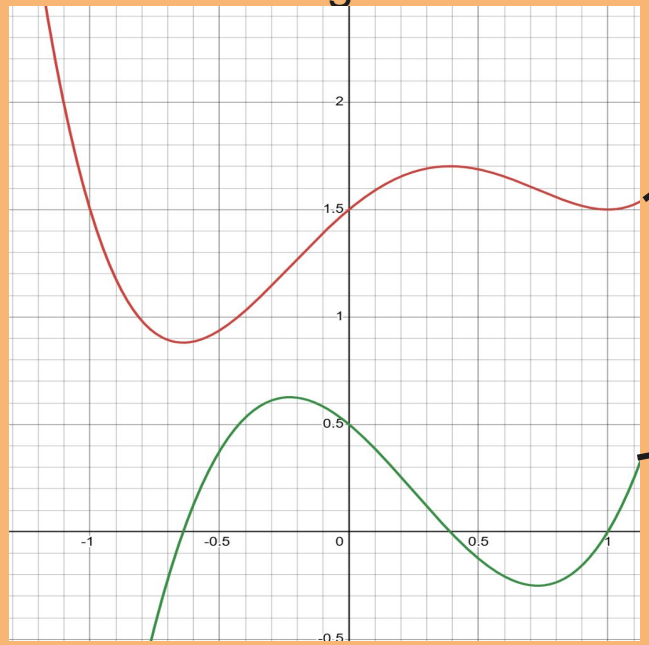
→**General principle: charges move so that they have as *little* potential energy as possible**

Voltage is all you need!

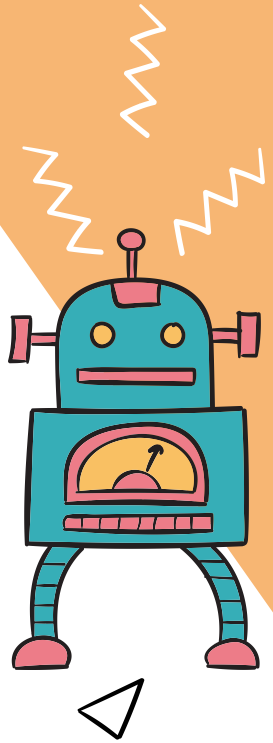
Due to mathematical reasons, we can define the voltage* at a point so that its spatial rate of change is the electric field (E = dV/dx)

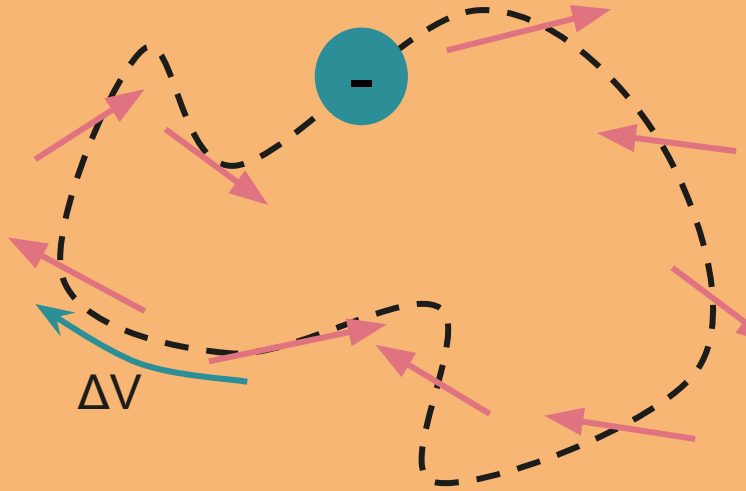
Then, the potential energy of a charge is just U = qV





Don't forget conservation of energy (kirchoff's voltage law)





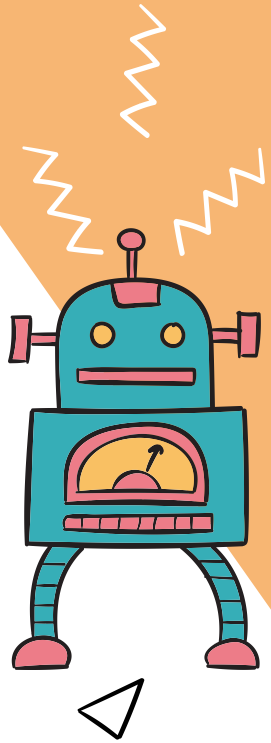
Under nice* conditions, moving a charge along a cyclic path cannot change its potential energy. Thus:

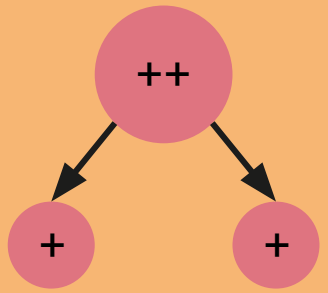
→ The sum of all ΔV along a cyclic path is zero

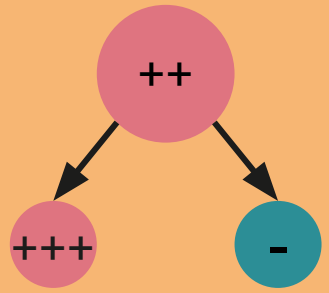
*in practice, we can account for ugly conditions with further voltage differences

Don't forget conservation of charge (kirchoff's current law)

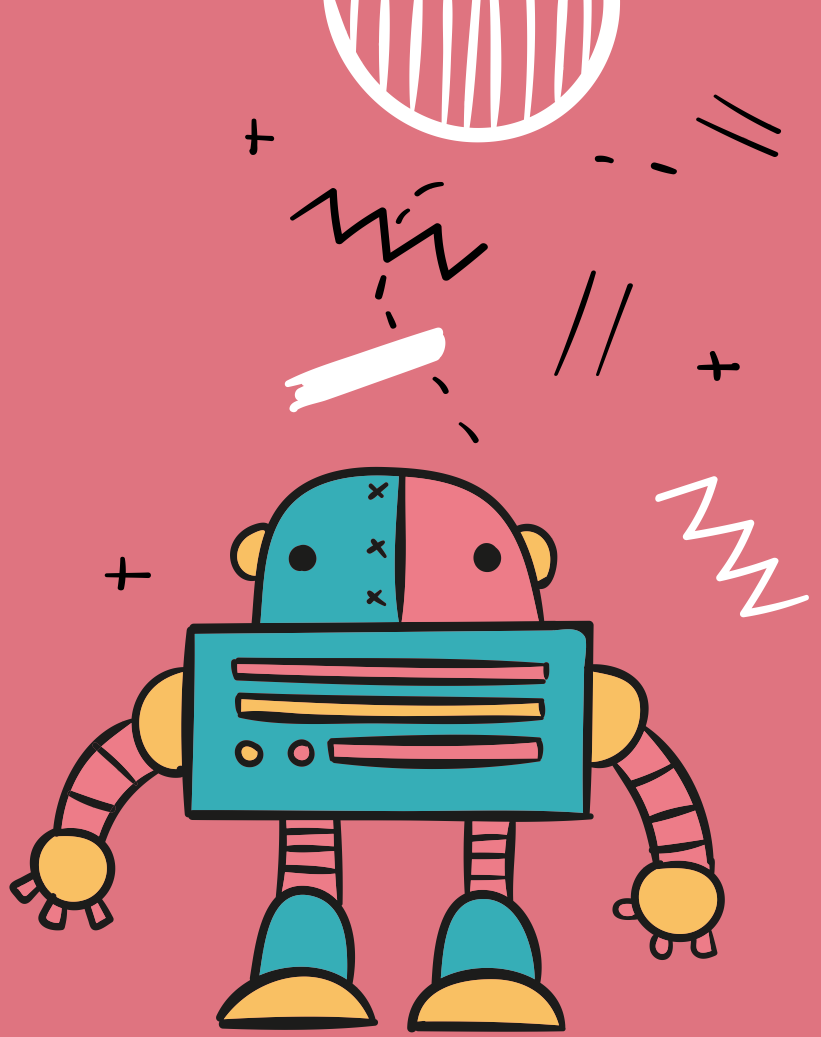
There is absolutely no way of making or destroying charge. All of it is always conserved.



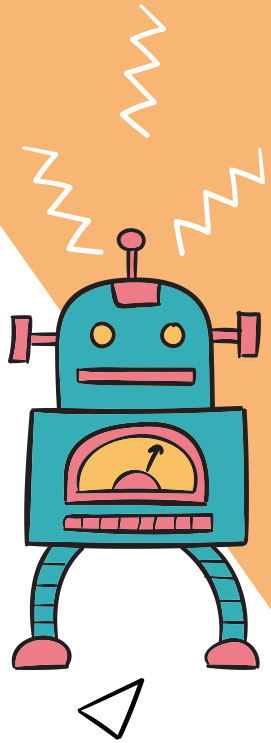


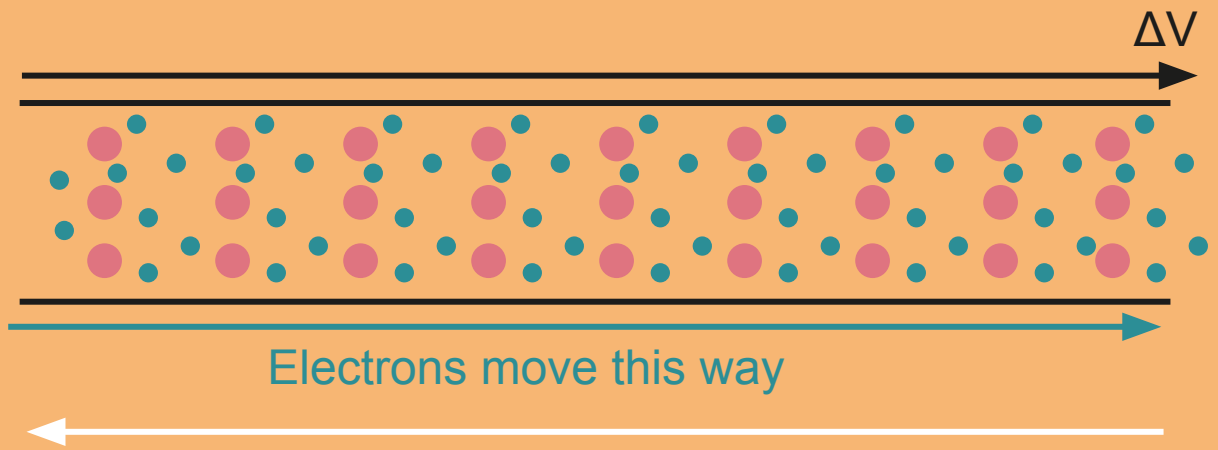


Building circuits



Metals have a sea of free electrons available to move

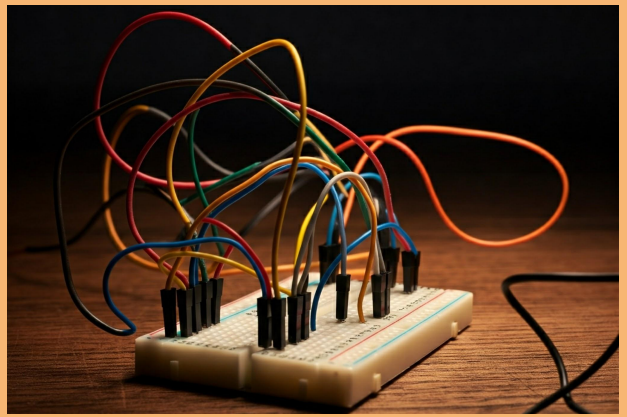


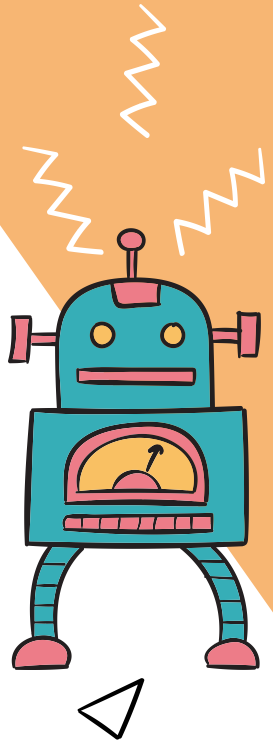


We call the movement of charges *current*. In practice, we treat it as if there were positive charges moving in the opposite direction

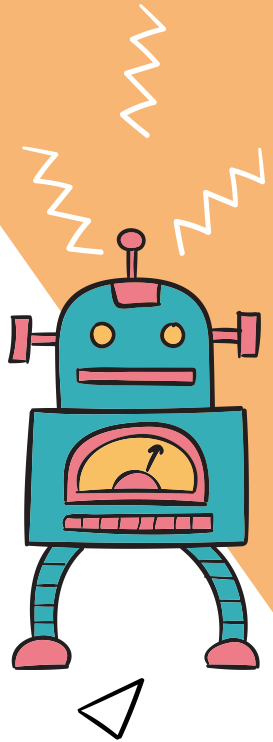
Wires

An (ideal) wire is a component that can conduct any amount of current without any voltage drop

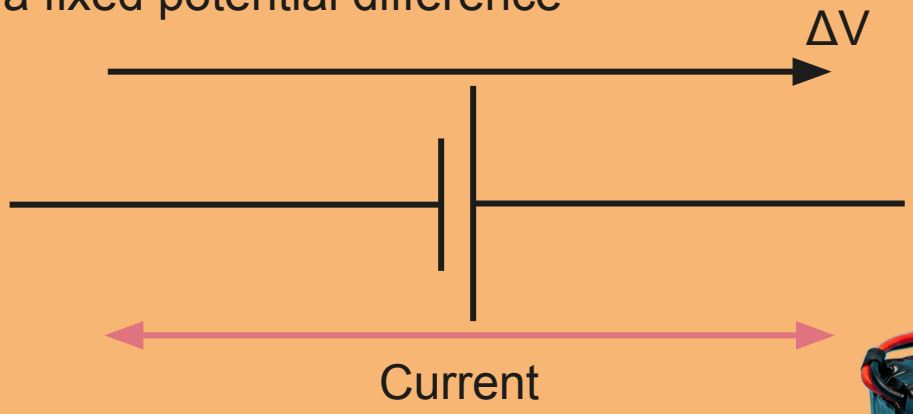




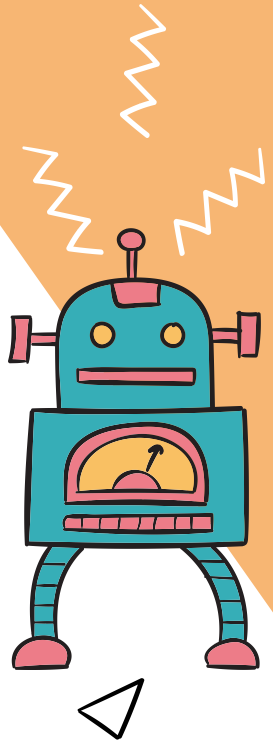
Batteries and voltage sources

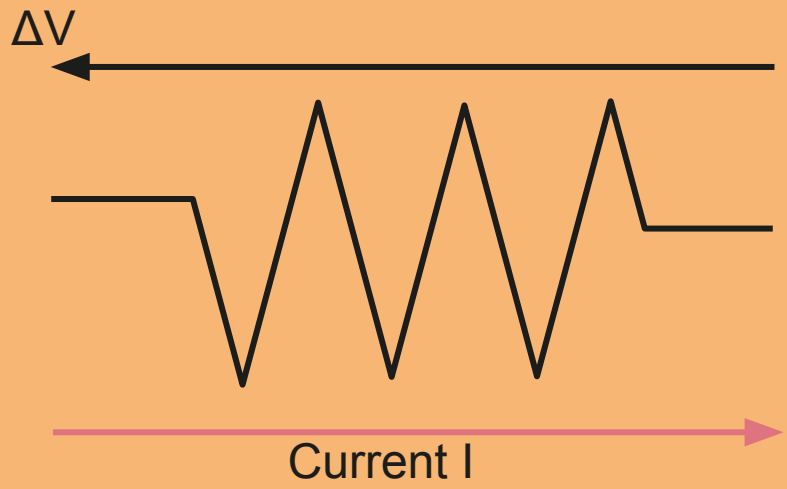


An (ideal) voltage source, or “battery”, is a component that can conduct any amount of current at a fixed potential difference

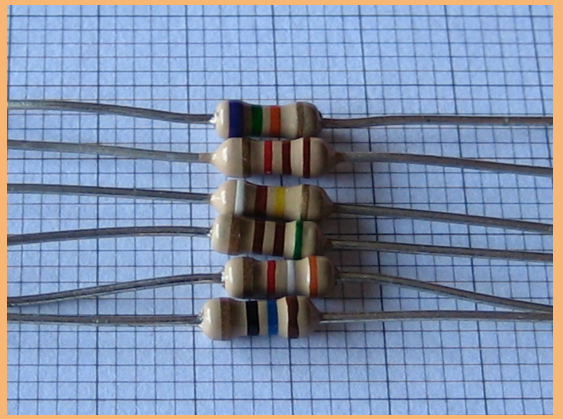


Ohm's law

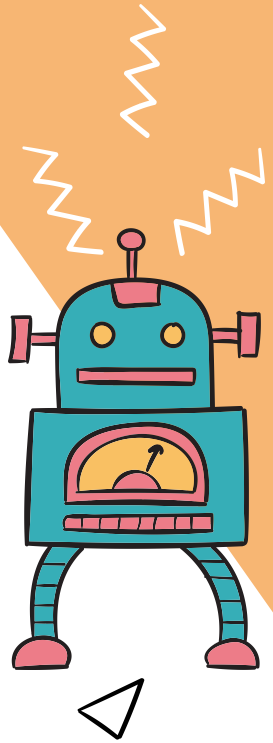


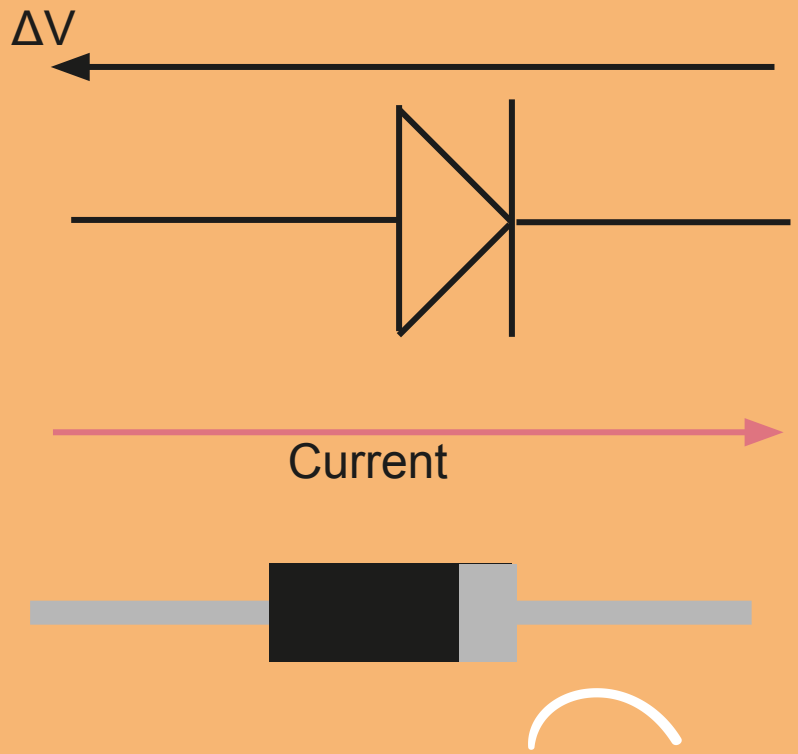


An (ohmic) resistor is a component that obeys ΔV = RI, for some constant R. We call R its resistance



Diode

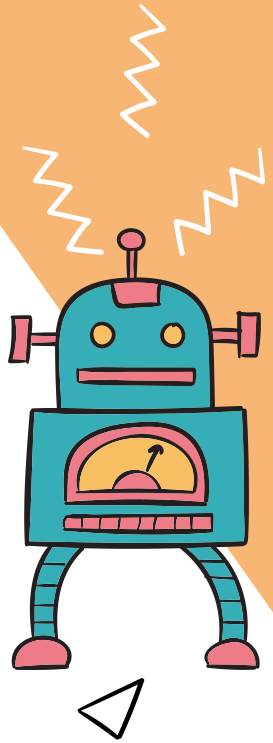


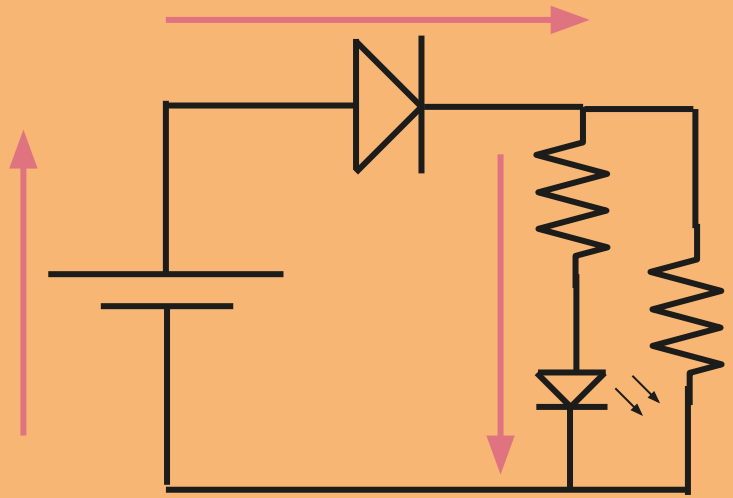


An (ideal) diode is a component that can conduct any amount of current, *in a single direction*, at a fixed voltage drop.

LEDs are diodes that emit light when current goes through them (longer leg is positive)

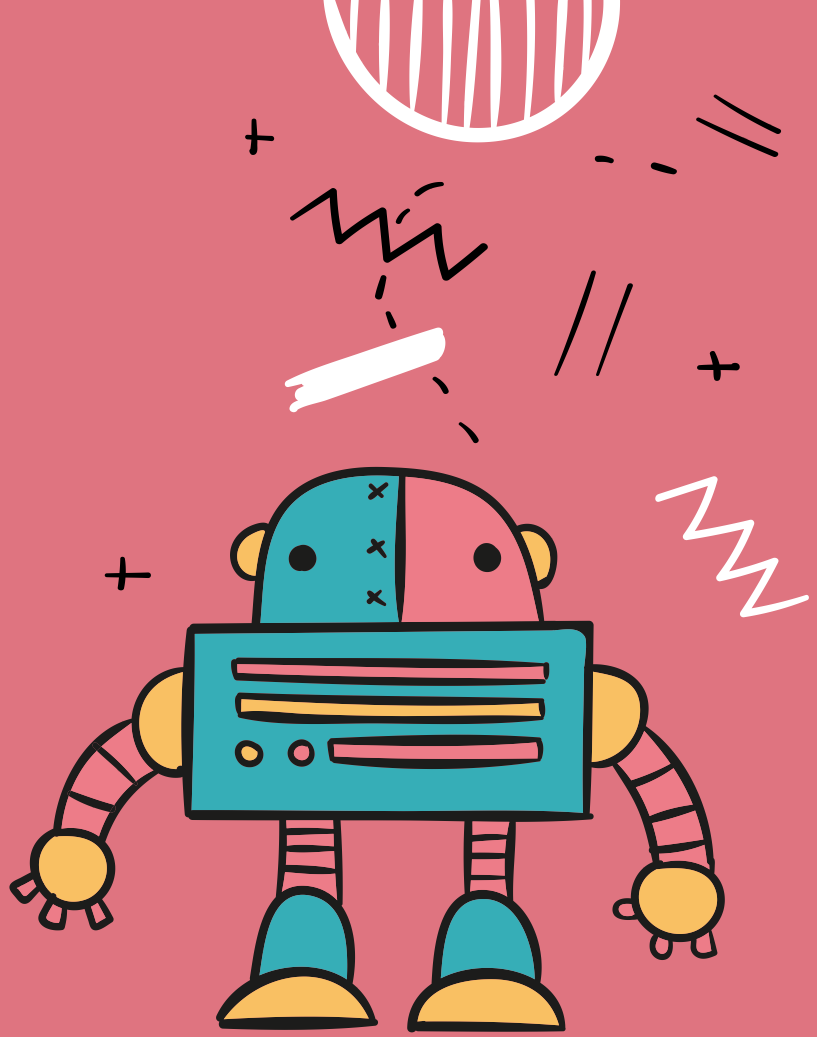
Using components to build circuits



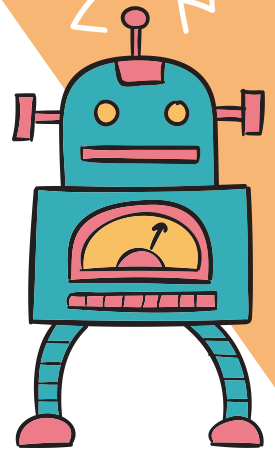


In practice, useful components have documents called *datasheets* that tell us how much voltage and current they need. Then we just need to wire a circuit capable of powering them.

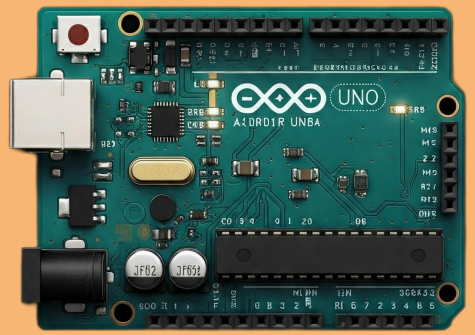
Digital electronics and logic



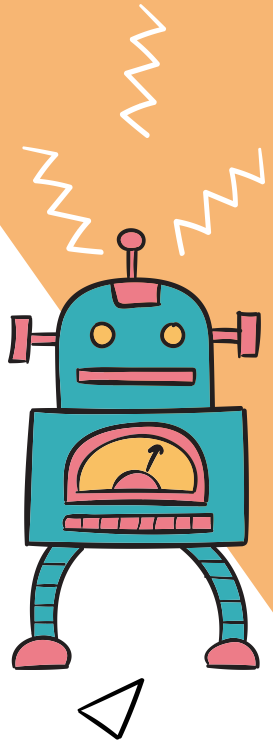
Digital electronics have two states



Very often, electronics operate just between two voltages: HIGH (e.g. 5V) and LOW (e.g. 0V). These are called digital electronics. We shall see some of them in the future, but the main one is the Arduino:



Boolean logic



We can abstract away HIGH and LOW voltages as 1 and 0 signals. Because they are ubiquitous across digital electronics, we need ways to combine multiple digital signals into a single one.

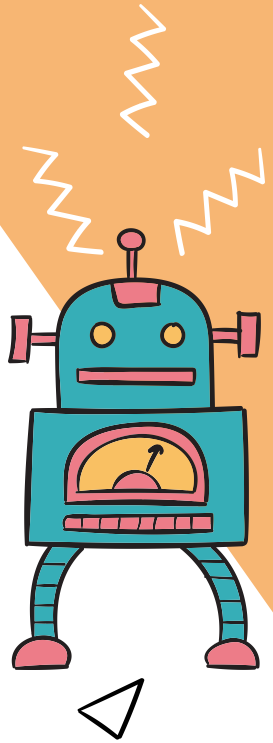
Furthermore, 1 and 0 can also represent truth values (e.g. 4 = 2 + 2 is a statement which has value 1). Therefore, the power of combining signals is the power of combining the truth of multiple statements into a single truth value. This will be crucial when programming.

AND operator

Let x and y be two statements (or signals). Then the AND operator && is such that:

X	Y	X && Y
0	0	0
0	1	0
1	0	0
1	1	1

Both need to be true



OR operator

Let x and y be two statements (or signals). Then the OR operator || is such that:

X	Y	X || Y
0	0	0
0	1	1
1	0	1
1	1	1

Either need to be true