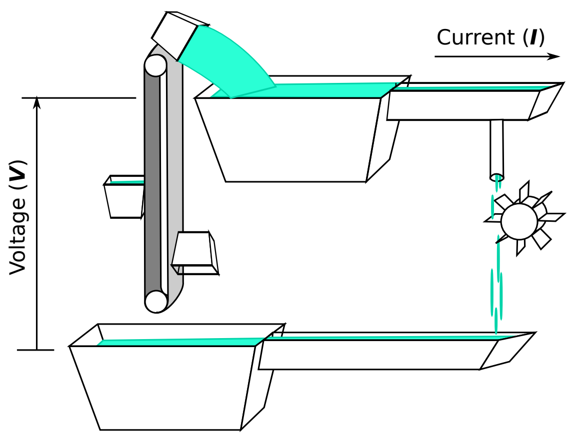
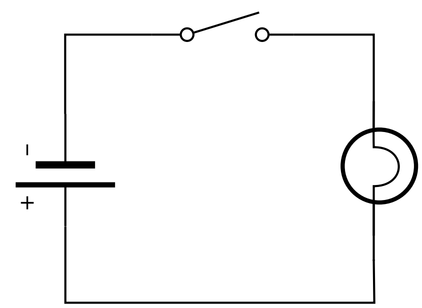
Prelab: Ohm's Law

Reminder: Charge, Voltage, Current

Let's remind ourself once more of the water analogy: https://www.youtube.com/watch?v=A097pVn5T58





Charge is the number of electrons. It's SI unit is the **Coulomb** (**C**), where one Coulomb corresponds to about 6 trillion trillion (6×10^{18}) electrons. It is analogous to a certain volume of water.

Current (symbol ***I***) is the number of electrons flowing through a piece of circuit per time. It's SI unit is the **Ampere** (**A**), which is just charge per time, i.e., 1 A = 1 C/s. It is analogous to a certain flow of water or amount of water per time.

Voltage (symbol ***V***) is the potential energy difference per electron between two points in the circuit. It's SI unit is the **Volt** (**V**), which is just energy per charge, i.e., 1 V = 1 J/C. It is analogous to the elevation of the water or water pressure.

Resistance

Open the following simulation and follow along as you read this document:
https://phet.colorado.edu/sims/html/circuit-construction-kit-dc-virtual-lab/latest/circuit-construction-kit-dc-virtual-lab_en.html

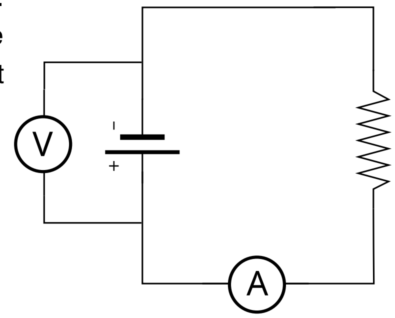
Voltage is determined by the type and number of batteries we use. The question is: how do we know the current, i.e., how much charge is flowing through our circuit? If we think back to our water analogy, this obviously depends on the type of circuit: if we just punch a big hole in the top water tank, the current will be very large. On the other hand, if we seal the pipe on the right, the current will be zero, as no water can flow through.

This property of a circuit to is known as **resistance**, defined as the voltage needed to allow a certain amount of current (how much the circuit "resists" to letting current through):

$$R = \frac{V}{I} \quad (1)$$

It's SI unit is the **Ohm** (Ω), which is given simply from the above equation as: $1\,\Omega = 1\,\mathrm{V}/1\,\mathrm{A}$.

To illustrate this in a circuit, build the circuit on the right in the simulation. (V denotes a voltmeter and A denotes an ammeter). The wiggly line represents a **resistor**, which is a circuit element with almost constant resistance *R*.

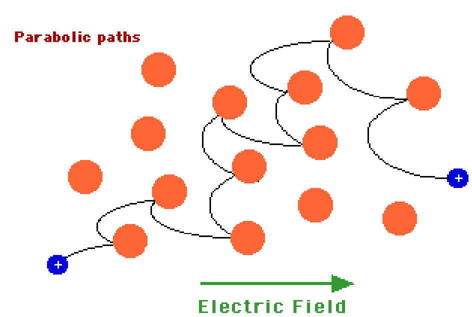


- Switch on the electrons.
- Click on the resistor. On the bottom, you see the resistance. Verify that current and voltage fit together given Equation (1) on the previous page.
- Click on the resistor and slowly dial up the resistance. Observe what happens to the voltage and the current.

It is often useful to make a graph of the current vs voltage across a circuit element. Such a graph is called the I–V or current–voltage curve. If this graph is just a straight line, i.e., if the resistance does not depend on current, the device is called "**resistive**" or "**ohmic**". Many devices are approximately ohmic, which is known as **Ohm's law**. However, not all devices show such behavior.

Where does resistance come from?

Resistance in a resistor comes from the fact that the electron collide with the atoms that make up the resistor (see picture on the right). This is similar to a "clogged pipe", where not as much current can flow through.



Resistance depends on temperature: the higher the temperature, the more the atoms in the resistor start to "shiver", which means that they present a bigger target to the electrons. Thus, usually, as the temperature increases, the resistivity increases.

Since the atoms are there at any temperature, it should always have *some* resistance. And indeed, this is observed for almost all materials, where as you cool it down, the resistance decreases, but it is always there. Then there is very curious type of material – a **superconductor**. In such a material, the resistance is *exactly* zero below a certain temperature under certain conditions. Superconductor technology is crucial to magnets used in medical imaging (MRI) and work is underway to develop applications for transmitting electrical power.