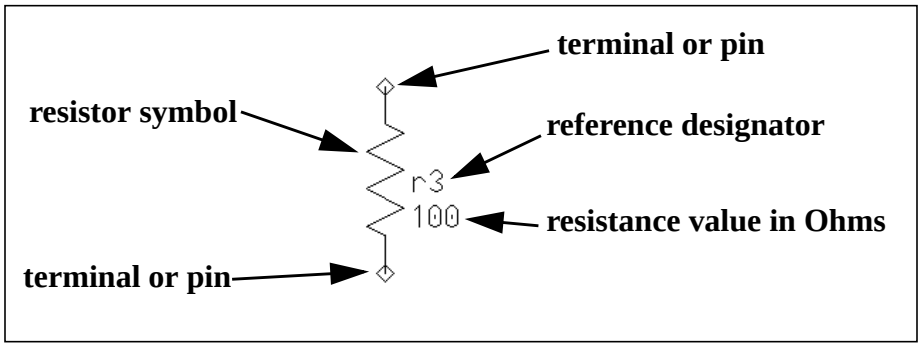
Resistors, Ohms Law, and the Passive Sign Convention

A wire is an ideal conductor with no resistance (at least for our discussion). In contrast, a *resistor* is a component that impedes or opposes the flow of electrons. The measure of opposition to the flow of electrons is measured in “Ohms”.

A water analogy: If current flow is water,.....
then wires are fire hoses,.....
and resistors are drinking straws.

The symbol for the resistor with its *reference designator* or instance name and its value in ohms is shown below.



To force more water through a drinking straw in a given amount of time, more pressure is required. We could express this mathematically as:

$$\textbf{rate of water flow} = \frac{\textbf{pressure applied}}{\textbf{how restrictive the hose is}}$$

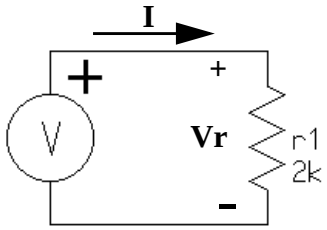
Electrically speaking:

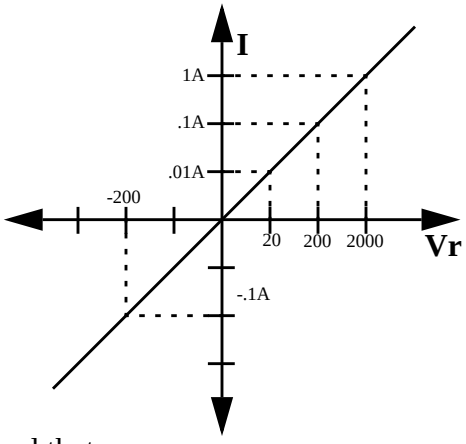
$$\textbf{current through conductor} = \frac{\textbf{voltage applied}}{\textbf{resistance}} \quad \Rightarrow \quad I = \frac{V}{R}$$

which implies: V = I *R (also written as: E = I * R)

The expression V = I * R is commonly known as *Ohms law.* It describes the relationship between voltage, current and resistance. It is the most fundamental formula in electrical engineering. This law discovered by George Simon Ohm in 1827. (Actually, it was discovered 46 years earlier by Englishman Henry Cavendish, a brilliant recluse, but nobody knew!)

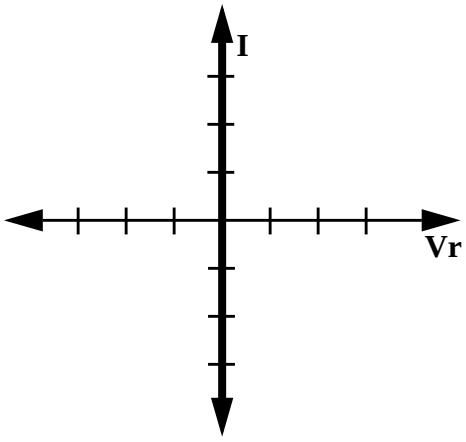
Below is a circuit consisting of a voltage source such as a battery and a resistor. Also shown is the graph relating current “I”, and the voltage Vr across the resistor r1 as the voltage source V is changed.





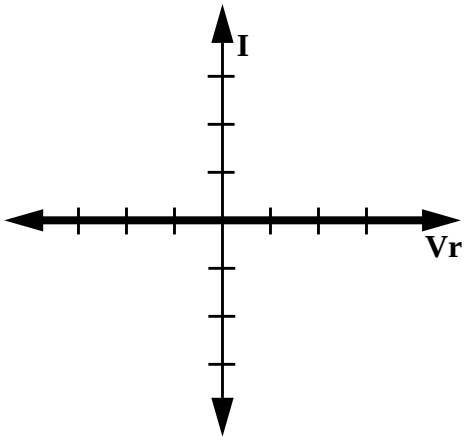
Note the linear relationship between I and Vr and that the line resides totally in the first and third quadrant of the graph. This is characteristic of a resistive element.

Now, lets take a graphical look at two special case resistors; *short circuit* and *open circuit*.



“Short Circuit”

Infinite current may flow through a perfect conductor but the voltage across the terminals is still 0.



“Open Circuit”

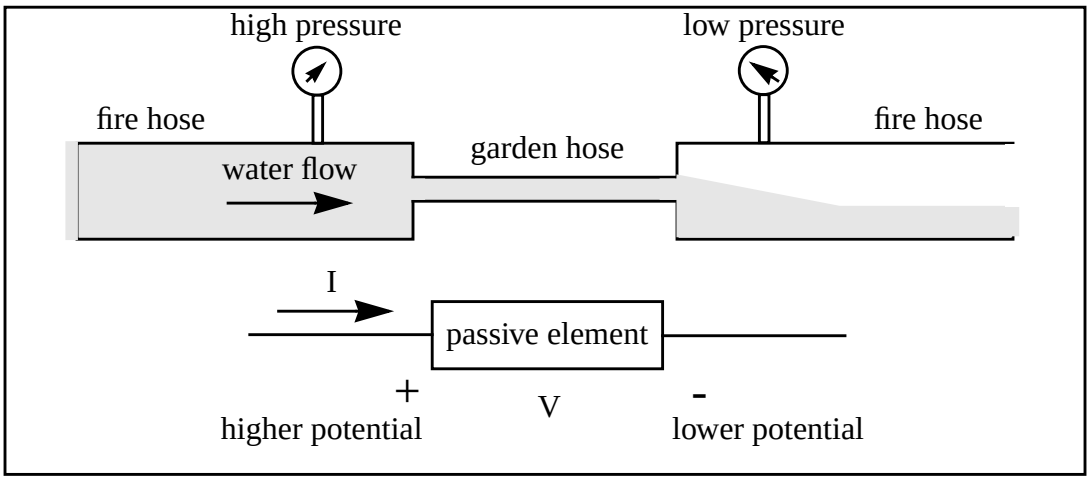
No current flows through a open circuit regardless of the voltage impressed across it.

The passive sign convention (*really important!*)

When we observe that positive current enters the positive terminal of a component, we say that the component obeys the *passive sign convention* (PSC). Therefore, when the passive sign convention is being obeyed, it indicates that a component is dissipating energy (or power) as charge is being displaced from a higher potential to a lower potential.

One way to think about this is using another water analogy. If we splice a garden hose in a length of firehose we create a pressure potential. The high pressure side is the one where the water is entering.

The garden hose is analogous to a resistor which impedes the flow of current. Thus, when current flows through a resistor, a higher voltage potential will exist on the incoming current side. In this example, the garden hose and the resistor are obeying the passive sign convention.



To reiterate, the PSC is obeyed when the current enters an element's positive terminal and exits at the negative terminal.

The passive sign convention is usually used for assigning reference marks for voltage drops across, and currents through, resistors, but we frequently assign a current and associated direction for a current through a voltage source in violation of the PSC. By the same token, we frequently define a voltage and its associated reference marks across a current source in violation of the PSC.

To successfully apply Ohms law, you must consistently observe the proper relationship between applied voltage and the direction of current flow.