Resistors and Ohms Law

A wire is an ideal conductor with no resistance (at least for our discussion). In contrast, a *resistor* is a component that purposefully impedes or opposes the flow of electrons. As an externlly applied electric field is applied to force current through a resistor, the electrons diffuse through the resistive material like a gas through a sponge. The electrons gain energy from the external field but once they start to move, they bump into a atom in the resistive material and loose some kinetic energy. How fast the electrons bump through the resistor depends on the intensity of the externally applied field. The stonger the field, the faster the electrons diffuse through the material increasing the number of electrons passing through per second. The speed at which electrons diffuse through the material is called the *drift velocity* and it is proportional to the applied voltage.

A water analogy: If current flow is water,.......

then wires are fire hoses,.......

and resistors are drinking straws.

To force more water through a drinking straw in a given amount of time, more pressure is required. Expressed as a water analogy:

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

Electrically speaking:

$$\text{current through conductor} = \frac{\text{voltage applied}}{\text{resistance}} \quad \text{OR}$$

$$I = \frac{V}{R}$$

$$\text{which implies: } V = I * R, \text{ and } R = \frac{V}{I}$$

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!) The measure of resistance to the flow of electrons is represented by "R"and is measured in 'Ohms'.
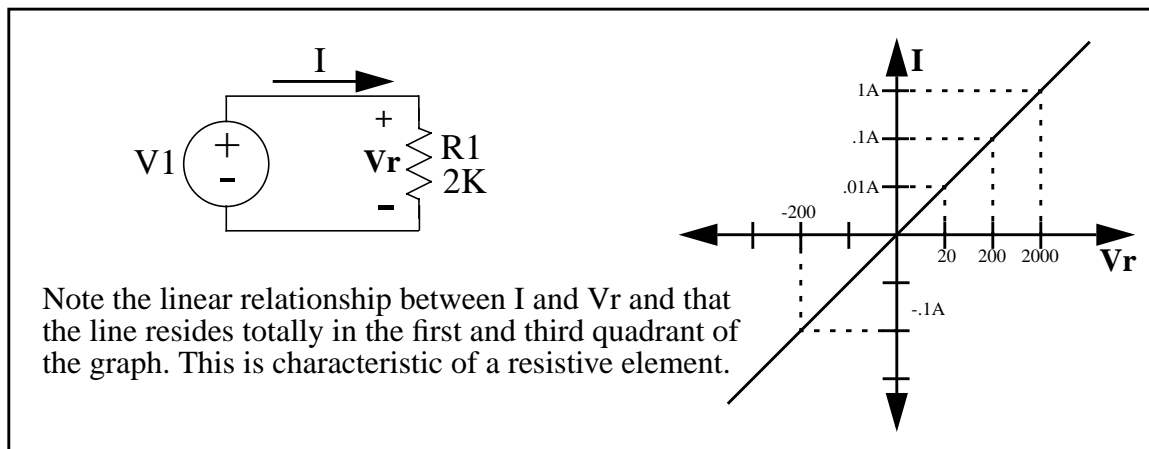
As the electrons bump their way through the material we must keep applying external energy to keep them moving. Each time the electrons collide with the resistor atoms, the electrical kinetic energy is given to the resistor atoms heating them up. Thus, one parameter that is specified with the resistance value is the ability of the resistance to pass its heat energy safely to the surrounding air.

The symbol for the resistor with its *reference designator* or instance name, its value in ohms, and its wattage is shown below. For most applications, the resistors have no wattage value attached to their symbol. Usually all the resistors are elsewhere specified to be all of one rating. We will speak more about watts and power dissipation later.
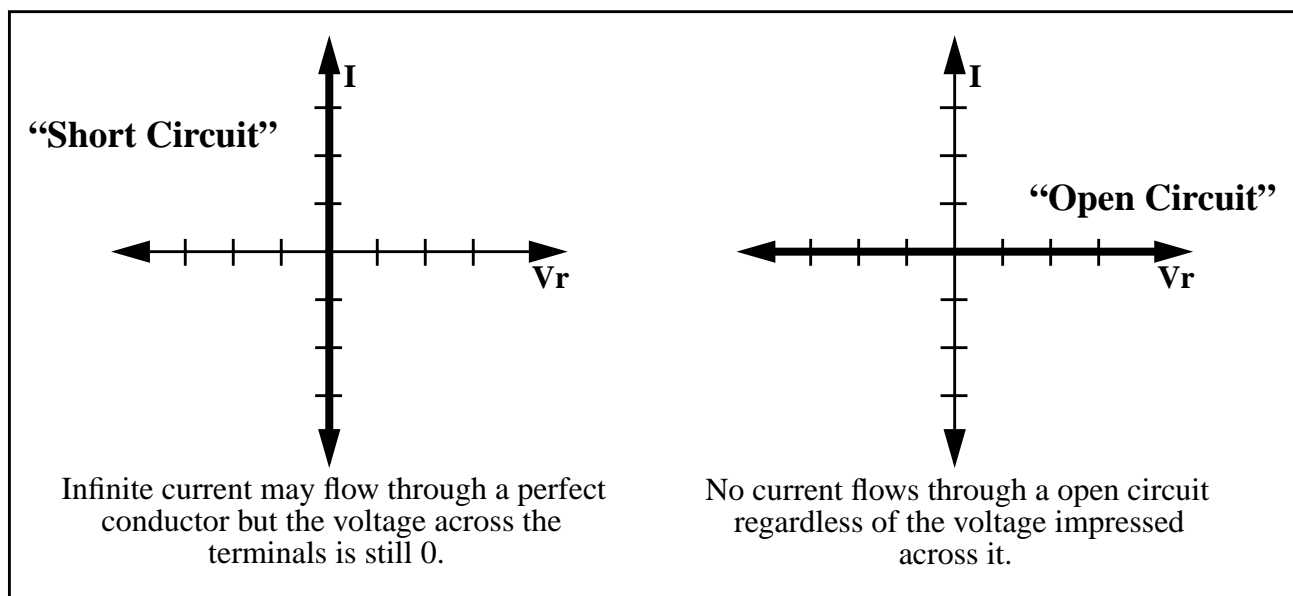
resistor symbol ⟶   R5 ⟵ reference designator

18 ⟵ resistance value in Ohms

wattage rating ⟶ 1/8W
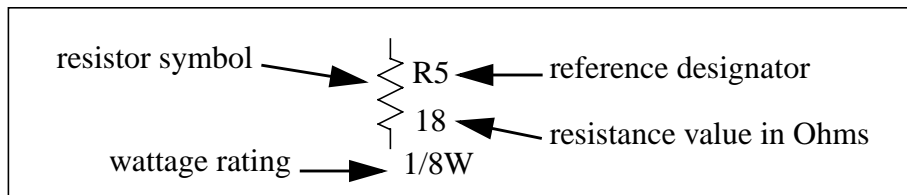
Graphical Representation of Ohms Law

Below is a circuit consisting of a voltage source and a resistor. Also shown is the graph relating current "I", and the voltage Vr across the resistor R1 as the voltage source V1 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.

Wires are zero ohm resistors

The wires in our schematic diagrams behave like a resistor whose value is zero. The schematic components in our example circuit are connected with wires which are assumed to be perfect in the sense that they exhibit no resistance to current flow. Since the wires are perfect, Ohms law tells us that

          1) the voltage at any point on the same wire is the same
          2) the voltage between any two points on the same wire is zero.

Meters M1 and M2 show that the voltage at any point on a wire is the same.

Meters M3 and M4 show that the voltage between any two points on the same wire is the same.
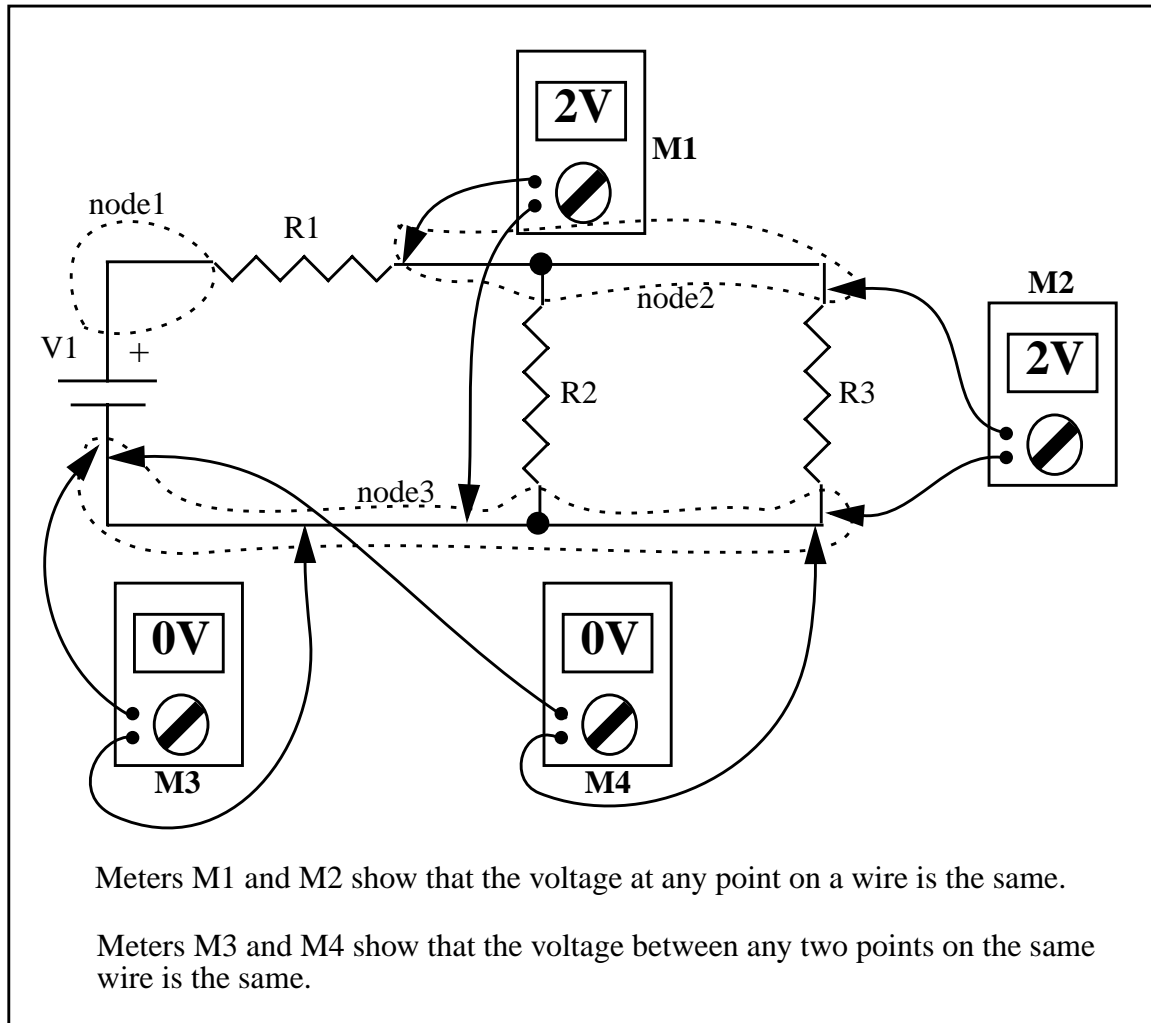
In the drawing the terminology of a *node* is introduced. A node on a schematic circuit is essentially a wire. Thus we can also say that the voltage anywhere on a node is the same. Also it holds that the voltage between any two points on a node is the same.

Resistors in Series

Circuit elements in *series* have the same current flowing through them. However, elements in series may have differing voltages across them.

When resistors are connected in series, their total combined resistance is the sum of their individual values. For example, in the circuit below, the equivalent resistance of the series connected resistors is $1 + 2 + 5 + 10 = 18$ ohms:

Resistors in series are equivalent to a single resistor equal to the sum of the individual resistances.
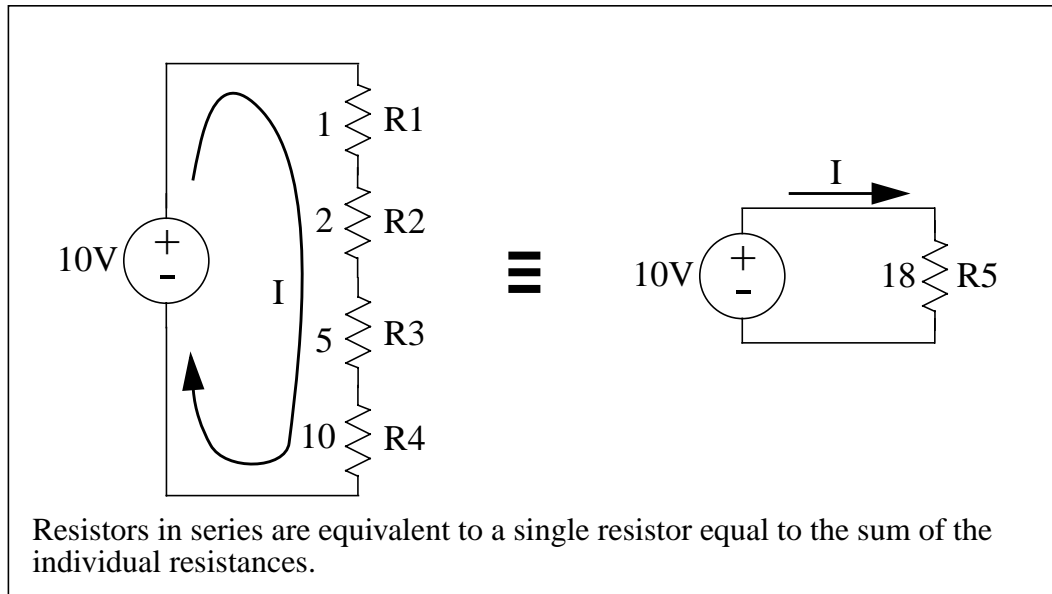
Thus, in the circuit above, the four series connected resistors can be replaced by a since 18 ohm resistor. We cannot prove this mathematically yet as we have not covered Kirchoff's voltage law. For now, it should be easy to accept the intuitive concept that concatenating opposition to current flow causes a simple additive increase in the opposition. Likewise, providing multiple resistive paths in parallel would lessen opposition. We will delay the proof of these claims until after we have looked at Kirchoff's current and voltage laws.