Ohm's Law and Voltage Dividers

For many materials, the flow of electrical current (*I* with units of amperes, A) through a device made of that material is proportional to the voltage (*V* with units of volts, V) across it. The ratio of voltage to current is then defined as the electrical resistance (*R* with units of ohms, Ω) of the device and depends upon its shape as well as the material from which it is made.

$$R \overset{\text{def}}{=} \frac{V}{I} \quad \text{for materials that obey ohms law.}$$

For incandescent lamps, transistors, and diodes (e.g. light-emitting diodes, LEDs) Ohm's law is **not** applicable. In those cases, there is a measured non-linear function *I*(*V*) or *V*(*I*) that must be used to characterize their electrical behavior.

We usually ignore the very small resistance of wires in a circuit, but devices called resistors are often required to control the flow of current.

Two useful facts:

1. **Voltages around a circuit add and the total equals the voltage powering the circuit.**
2. **Current flowing into a device must flow out of the device.**

These two facts imply that resistors wired in series act like a single resistor with a resistance that is the sum of the individual resistances: $R_{\text{total}} = R_1 + R_2$ for resistors wired in series.

So if we have 5.0 V across two resistors in series, one with 1800 Ω and the other with 1000 Ω, we can consider that to be 5.0 V across 1000+1800=2800 Ω. Using Ohm's law, the current through that series combination of resistors is:

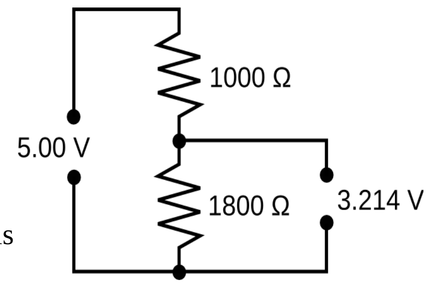
$$I = \frac{V}{R_{\text{total}}} = \frac{5.0\,\text{V}}{2800\,\Omega} = 0.001786\ \text{A} = 1.786\,\text{mA}$$

Using Ohm's law applied to each resistor separately, the voltage across each resistor is:

$$V_1 = I\,R_1 = (0.001786\,\text{A})\cdot(1000\,\Omega) = 1.786\,\text{V} \quad \text{and} \quad V_2 = I\,R_2 = (0.001786\ \text{A})\cdot(1800\,\Omega) = 3.214\,\text{V}$$, respectively.

These add up to 5.000 V as they must by rule 1 above.

A voltage divider circuit using these resistors looks like this:



5.000 V powering the left side of this voltage divider provides 3.214 V on the right side. The calculation assumed that no current flows out the right side.

As long as any circuit connected to the right side requires **much** less than 1.786 mA, this assumption is justified. If not, the voltage will be become less than 3.214 V. The current drawn by the Raspberry Pi pins when set for input is sufficiently small to not significantly change the result of this calculation.

Keep in mind:

Excessive voltage across a devices causes excess current through the device.
Excess current through a device causes excess heating.
Excess heating burns out the device.
The Raspberry Pi circuits are powered by 3.3 V.
Never put more than 3.3 V across any pin of the Raspberry Pi.
The ATmega328P processor can be powered by 3.3 V as in the Gertboard, or by 5.0 V as in the Arduino
Never put more than 3.3 V across the ATmega328P pins in the Gertboard or more than 5.0 V across the ATmega328P pins in an Arduino.

Devices powered by 5.0 V may be connected to the Raspberry Pi **only if a voltage divider is placed on all outputs from the devices going into the Pi** in order to lower the output voltage to 3.3 V. The 3.3 V logic levels **output** from the Pi, however, are usually sufficient to control the **input** circuits of 5.0 V devices and may be directly connected.