What is Electricity?

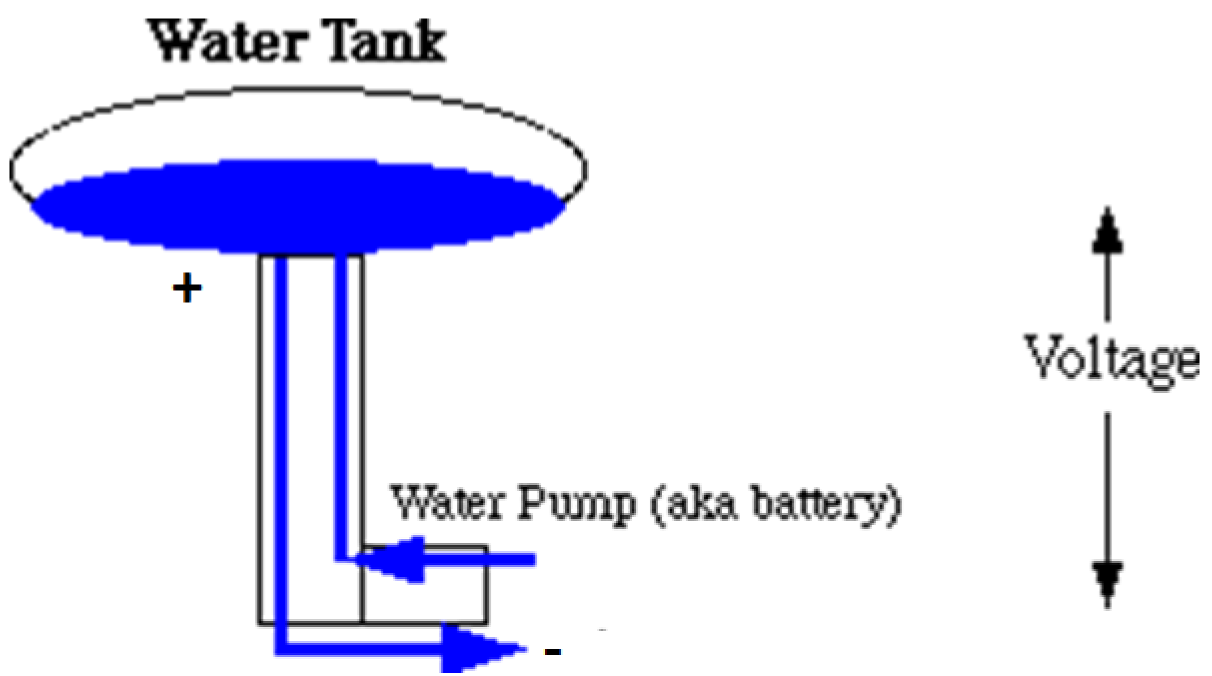
Electricity is the flow of tiny charged particles called electrons.

Electrons are present in all substances, but in some materials they are not free to move. These substances are known as insulators.

Substances which permit the flow of electricity are called conductors.

There are three basic electrical characteristics that come into play in every circuit:

- Voltage
- Current
- Resistance



To describe how circuits work, we can compare to how water flows:

Amount flowing = Current

Pressure (difference in level) = Voltage

Things blocking or slowing down flow = Resistance

Current

The amount of electrons that is flowing through the wires of the circuit

Current is measured at a single point in a circuit (flow thru the point)

Current is measured in units of amperes, shortened to amps

Voltage

A force that pushes the current through the circuit (in this picture it would be equivalent to gravity)

Voltage is the relative level of energy between any two points in the circuit (for example between power and ground). You can think of it as height of water above ground level.

Voltage is always measured across two points in a circuit

Voltage is measured in units of volts

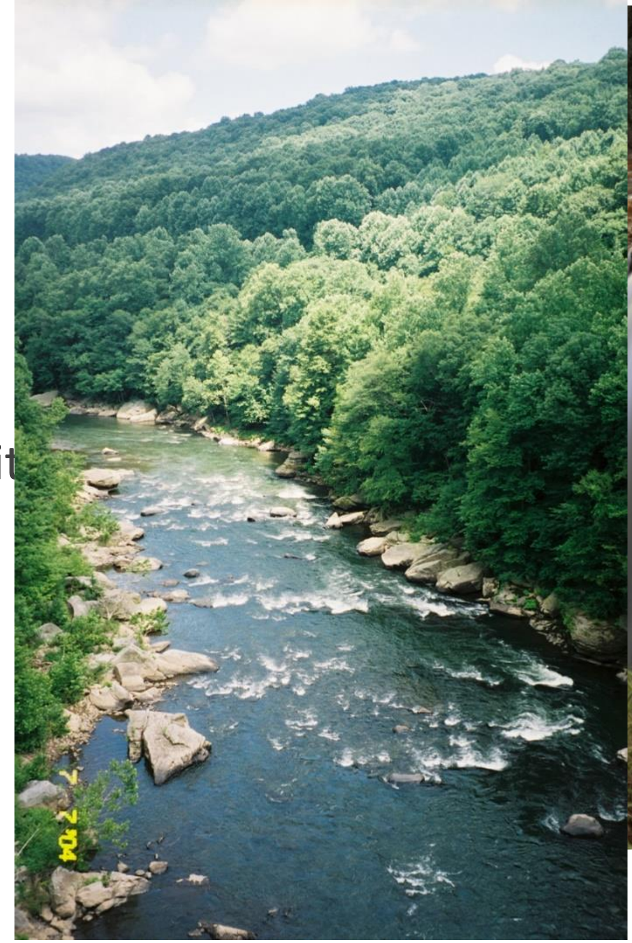
Resistance

The amount that any component in the circuit resists the flow of current (like rocks or narrows in a river)

Resistance is always measured across two points in a circuit

Resistance is also called load.

Resistance is measured in units of Ohms



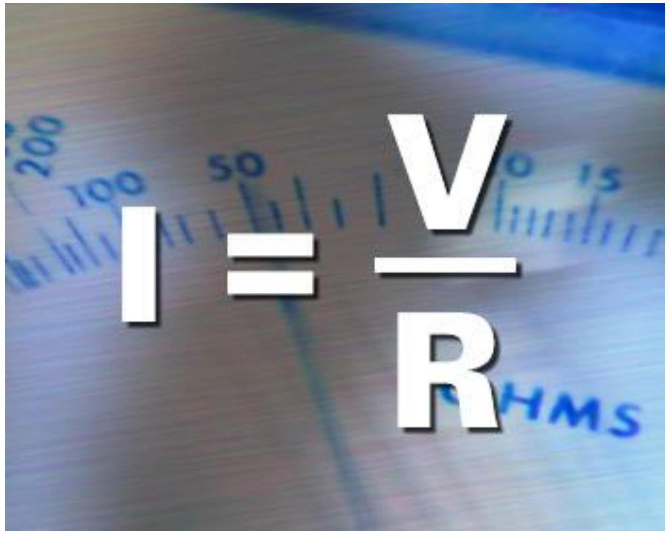
Power Sources

Batteries, power supplies (like for your phone or laptop), and AC outlets act like a pump pumping water up a hill.

- They take electrons with low energy (at ground level) and move them to a high energy (like moving water up a hill or into a tall water tower)
- Creates electrical pressure – voltage
- Current, like water, naturally flows from high energy to low energy (down the hill) unless blocked by resistance and insulators.
- The low energy side of a battery is called the negative or ground (-), and the high energy side is called the positive (+).
- A power source’s stated voltage is the pressure difference between the + and the - sides.

Formulas: Ohm's Law

Voltage, current and resistance in a circuit (or any part of the circuit) are all related by Ohm's law.



Voltage = V

Current = I

Resistance = R

The combination of current and voltage is called electrical power. It is measured in watts. The relationship is:

watts = volts x amps
(P=V*I)

Circuits

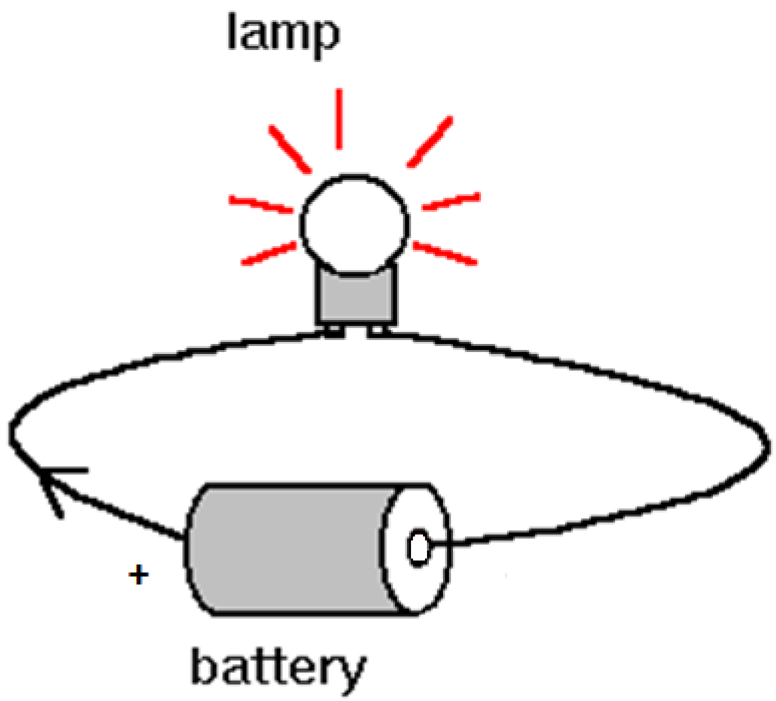
A circuit is a closed loop containing a source of electrical energy (e.g., a battery) and a load (e.g., a light bulb)

Electrons naturally flow from the high energy (+) side to the low energy (–) ground side.

Resistive (load) components usually do some work – light up, turn a motor, …

- What would the current be if the circuit resistance was 0? (see Ohm's Law)
- Called a short circuit – and is not good!

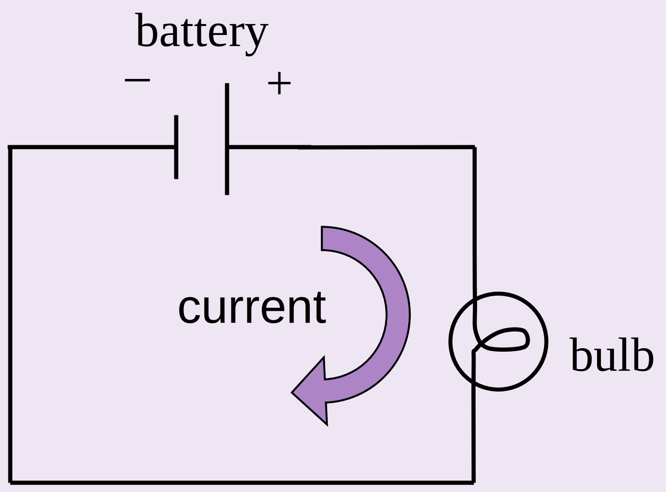
Conductors (usually wires) are used to move electrons from the battery to the circuit components.



Would This Work?

The Central Concept: Closed Circuit

Circuit in Diagram Form



In a closed circuit, current flows *around* the loop

Circuit Components

- Resistors
- Switches
- Diodes & LEDs
- Others: Capacitors, Inductors, “Chips”

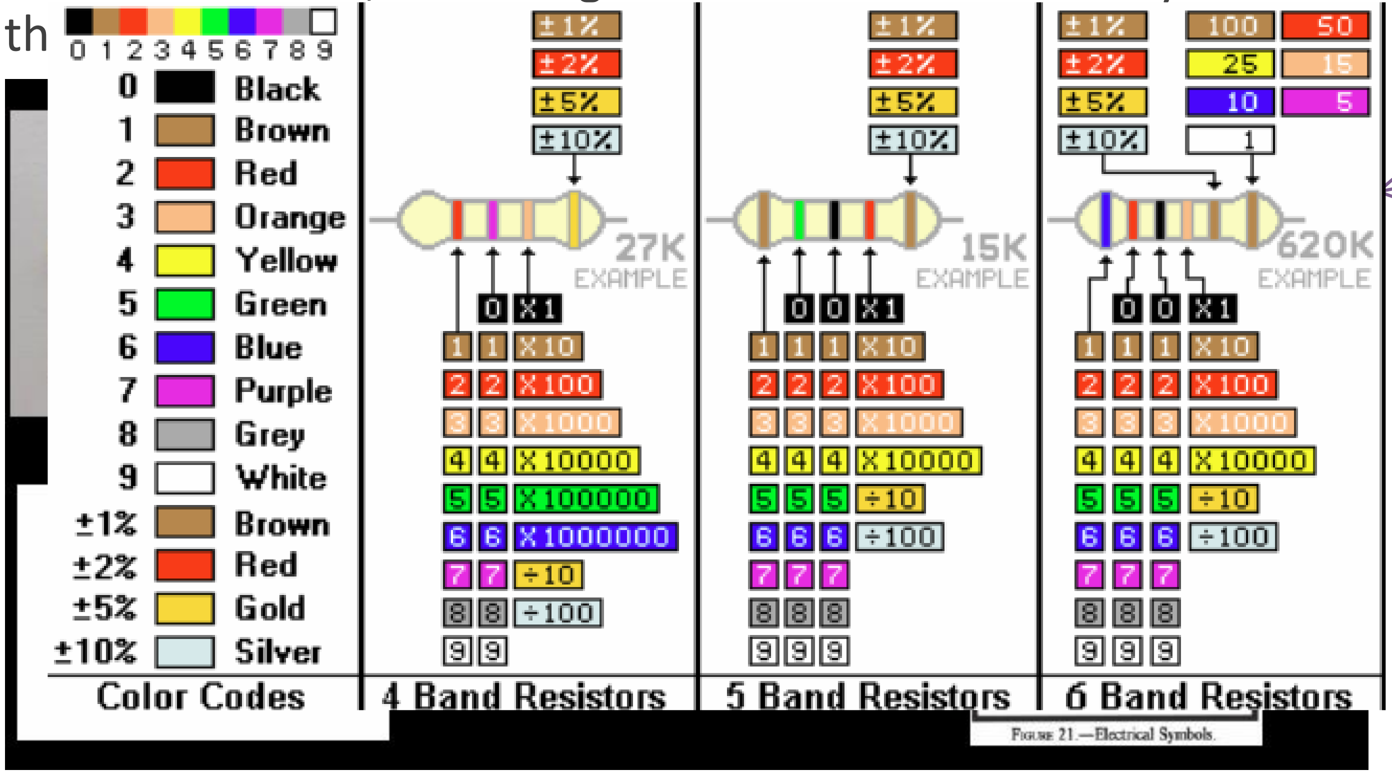
Resistors

Resistors give electricity something - they convert electrical energy into heat.

The value of a resistor is written right next to its schematic symbol in a circuit diagram.

Resistors are rated in ohms, indicating how much resistance they offer a circuit, and in watts, indicating th

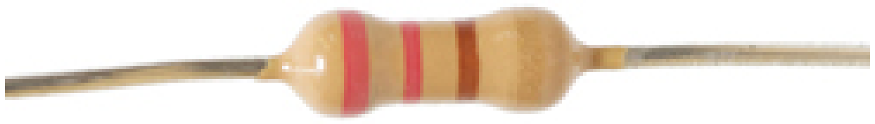
Fixed Resistors



Variable Resistors

Resistors also are rated for maximum wattage. This is determined by size. The small ones that come with the kit are rated for ¼ watt.

What is the resistance?

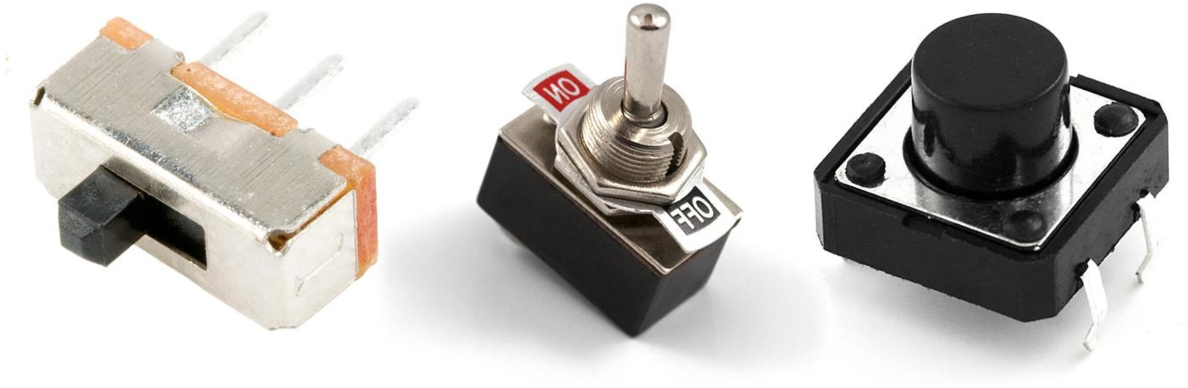


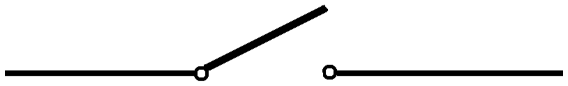
Switches

Switches passes or interrupt the flow of electricity

A simple switch has two interchangeable leads. The leads are attached to two contacts inside the switch that can put them in contact with each other or be separated by the actions of the switch.

Momentary vs. toggle switches

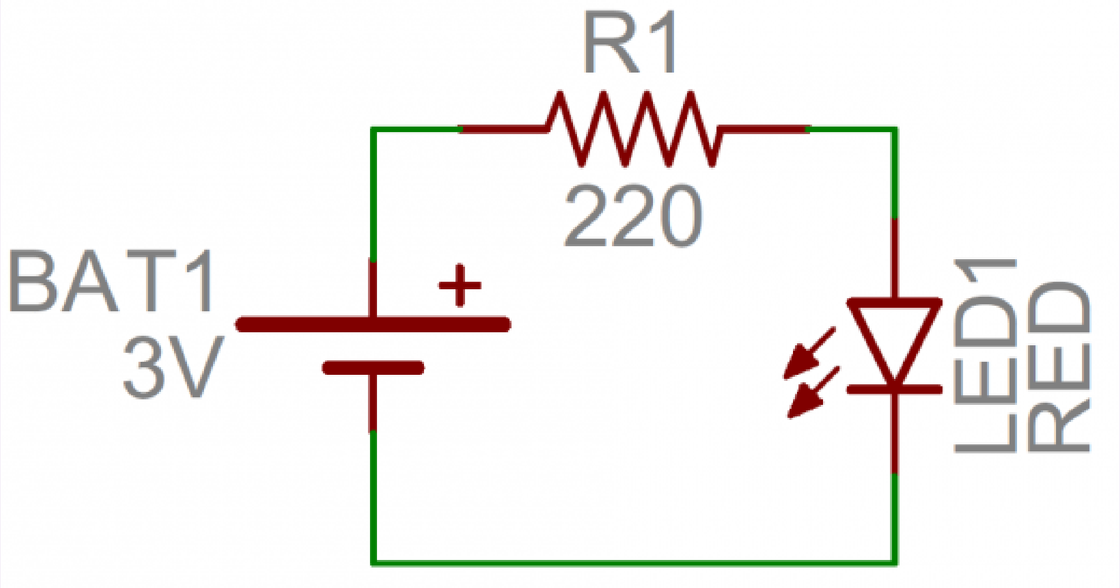




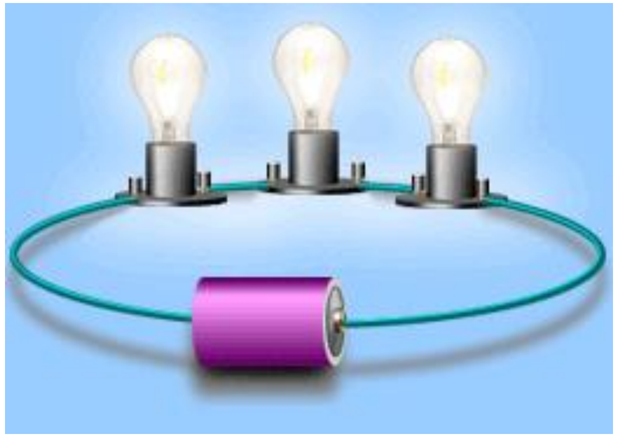
Naming Convention in Circuit Diagrams

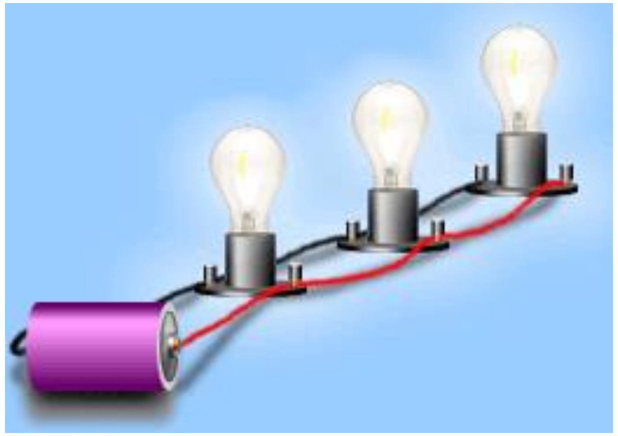
Identifier	Component
R	Resistors
C	Capacitors
L	Inductors
S	Switches
D	Diodes/LEDs

Circuit Diagram Example



Simple Circuits





Series circuit

- All in a row
- 1 path for electricity
- 1 light goes out and the circuit is broken

Parallel circuit

- Many paths for electricity
- 1 light goes out and the others stay on

Formulas for Series Circuits

Using **V = I*R**, we see that in **series** the same current must move through both resistors.

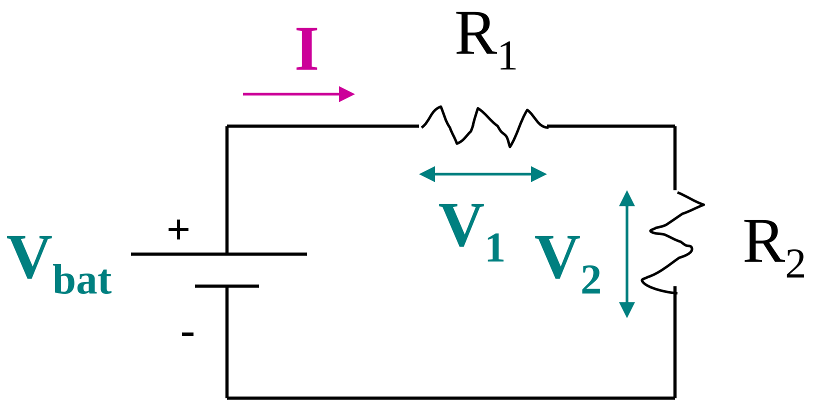
The voltage drop across the two resistors adds to give the total voltage drop

(Analogy: Think of each resistor as a waterfall. The total height that the water falls is the addition of the heights of the two waterfalls.)

$$V_{total} = (V_1 + V_2)$$

$$R_{eff} = R_1 + R_2$$

$$I = V_{total} / R_{eff}$$

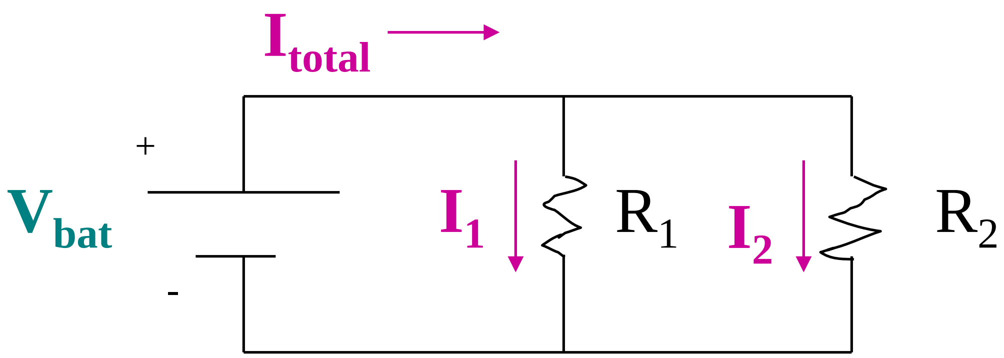


Formulas for Parallel Resistors

In a parallel circuit, the voltage drop for each path is the same, but the current is different

(Think of water in a river that splits with some water flowing over one fall and the rest falling over the other but all the water ending up joining back together again.)

Current into any branch or merge point must be equal to the current leaving the point.



The amount of current that goes down each path depends on its resistance.

- Low resistance – more current
- High resistance – less current

$V_{total} = V_1 = V_2$

$I_{total} = (I_1 + I_2)$

$1/R_{eff} = 1/R_1 + 1/R_2$ or $R_{eff} = 1 / (1/R_1 + 1/R_2)$

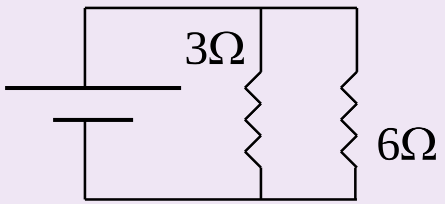
Parallel & Series Circuit Examples

Consider two resistors in **parallel**: a 3Ω and a 6Ω resistor:

$1/R_{eff} = 1/R_1 + 1/R_2 = 1/3\Omega + 1/6\Omega = (.333/\Omega + .167/\Omega) = .5$

or $R_{eff} = 1/.500 = 2\Omega$

Note that 2Ω is smaller than the smallest single resistor of 3Ω.



5V power supply again.

What is the voltage drop on each branch? 5V (same for all paths)

What is the total current and the current in each branch?

$I_1 = V/R_1 = 5 / 3 = 1.67$ amps

$I_2 = V/R_2 = 5 / 6 = 0.83$ amps

$I_{total} = I_1+I_2 = 1.67+0.83 = 2.5$amps (alternatively, $I_{total} = V/R_{eff} = 5/2 = 2.5$ amps)

Your Turn!

V?

Voltage drop between points

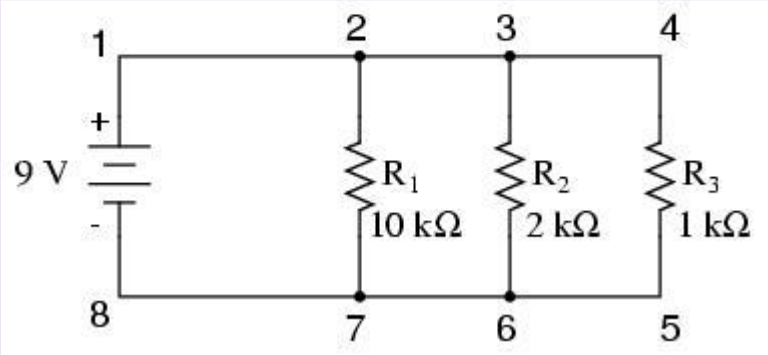
- 2 and 7?
- 3 and 6?
- 1 and 2?

R_{eff}?

I_{total}?

$I_{4\text{-}5}$?

- Will this be larger or smaller than $I_{2\text{-}3}$?



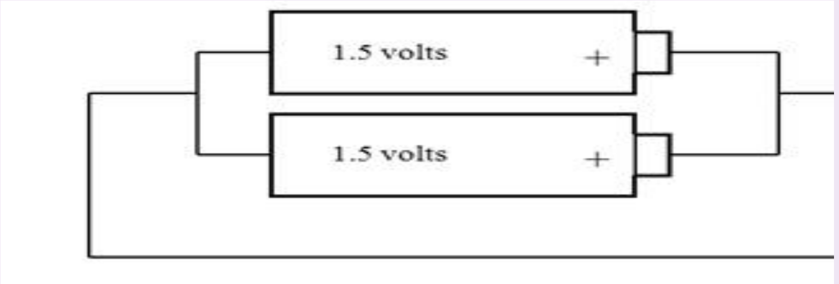
Series or Parallel Power Supplies

Series and parallel also applies to batteries & other power sources.

- For batteries in series, the voltage are added. For example, a D cell battery supplies 1.5 volts, so four D cell batteries in series (one after the other) will supply 6 volts but at the same maximum current as a single battery.
- Batteries in parallel keep the same voltage, but combine the amount of current they can combine. So 4 D batteries in parallel would still provide 1.5 volts, but could provide 4 times as much current to the circuit if needed.

Two 1.5v batteries with current capacities of up to 1 amp each are arranged as shown

- Total voltage?
- Total current capacity?

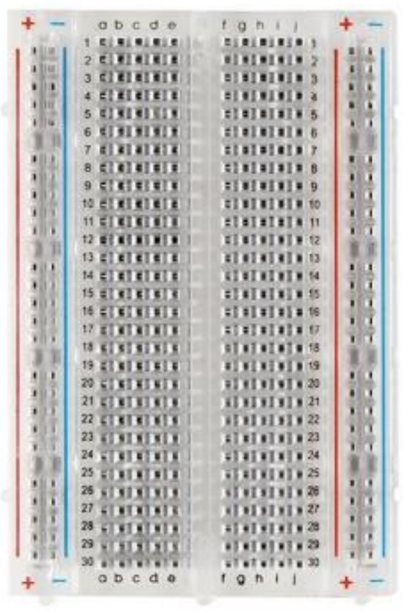


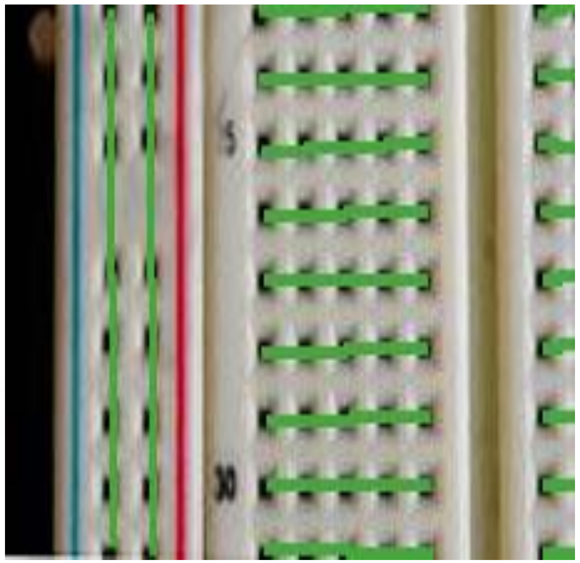
You have a bunch of 1.5v batteries. How would you arrange them in order to have a 6 volt power source?

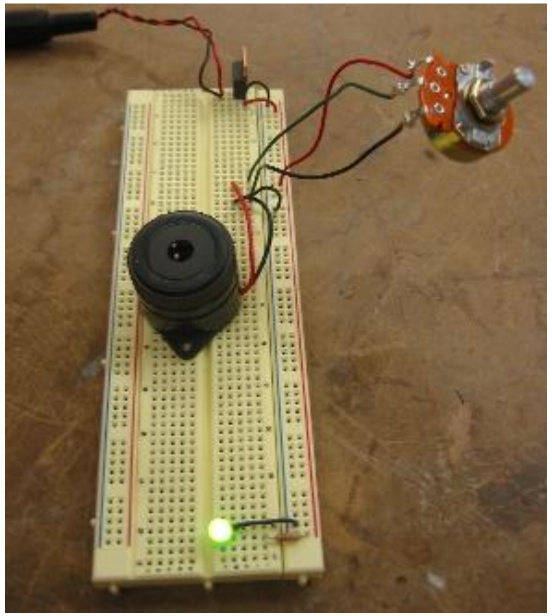
Breadboards

A breadboard is a tool for holding the components of your circuit, and connecting them together.

It’s got holes that are a good size for wires and the ends of most components, so you can push wires and components in and pull them out without much trouble.







Wires (Conductors!)

Red wires used for + connections

Black (and sometimes green) used for ground (-) connections

Other colors used for connecting components