Tinkercad Circuits & EV Motor Workshop

Part 1: Intro to Circuits

& Circuits Simulator

ASPIRE
NSF Engineering Research Center

Engineering & Applied Science
UNIVERSITY OF COLORADO BOULDER

INTEGRATED
TEACHING & LEARNING
Program and Laboratory

What You'll Need!

Computer, Mouse & Internet Connection

Microsoft Windows 10, Apple OSX10.10, or Chrome OS on Chromebooks

+

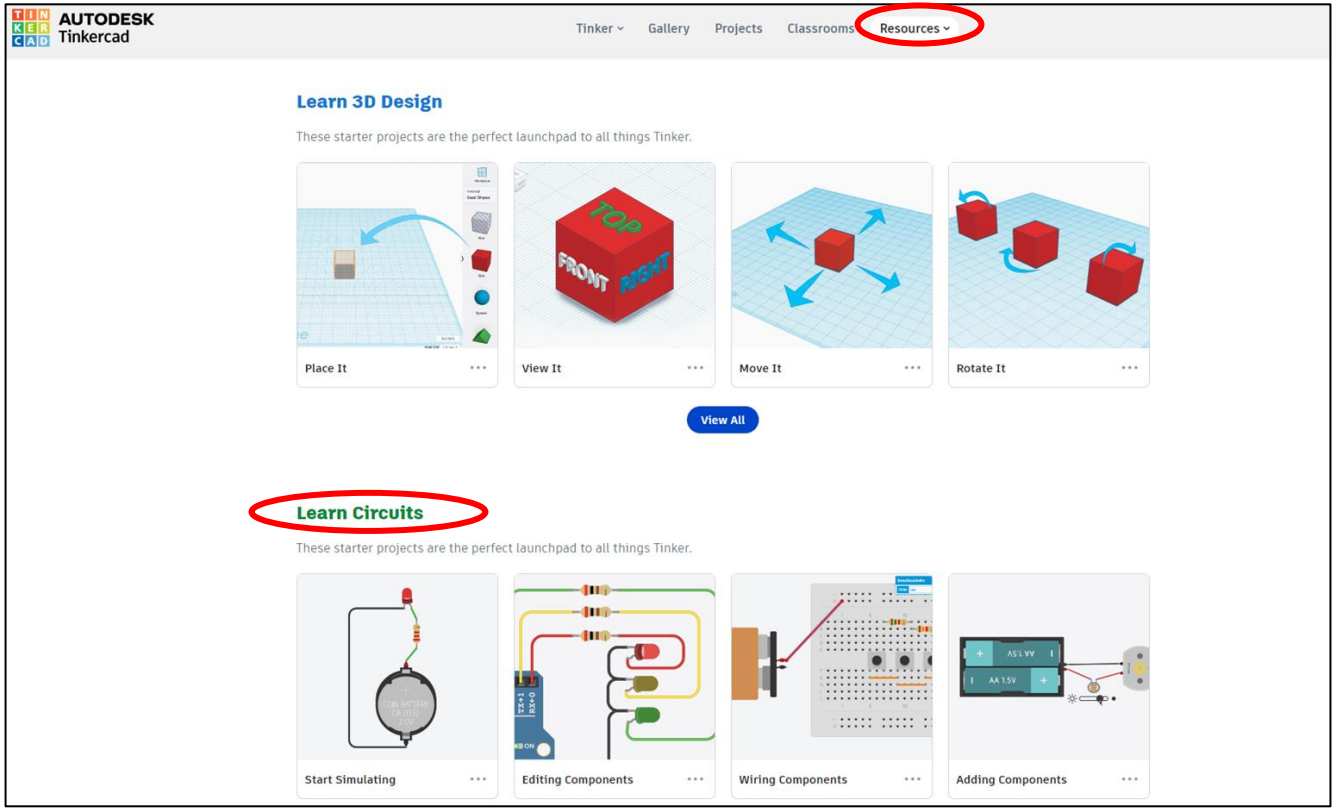
TinkerCAD Account

Go to https://www.tinkercad.com

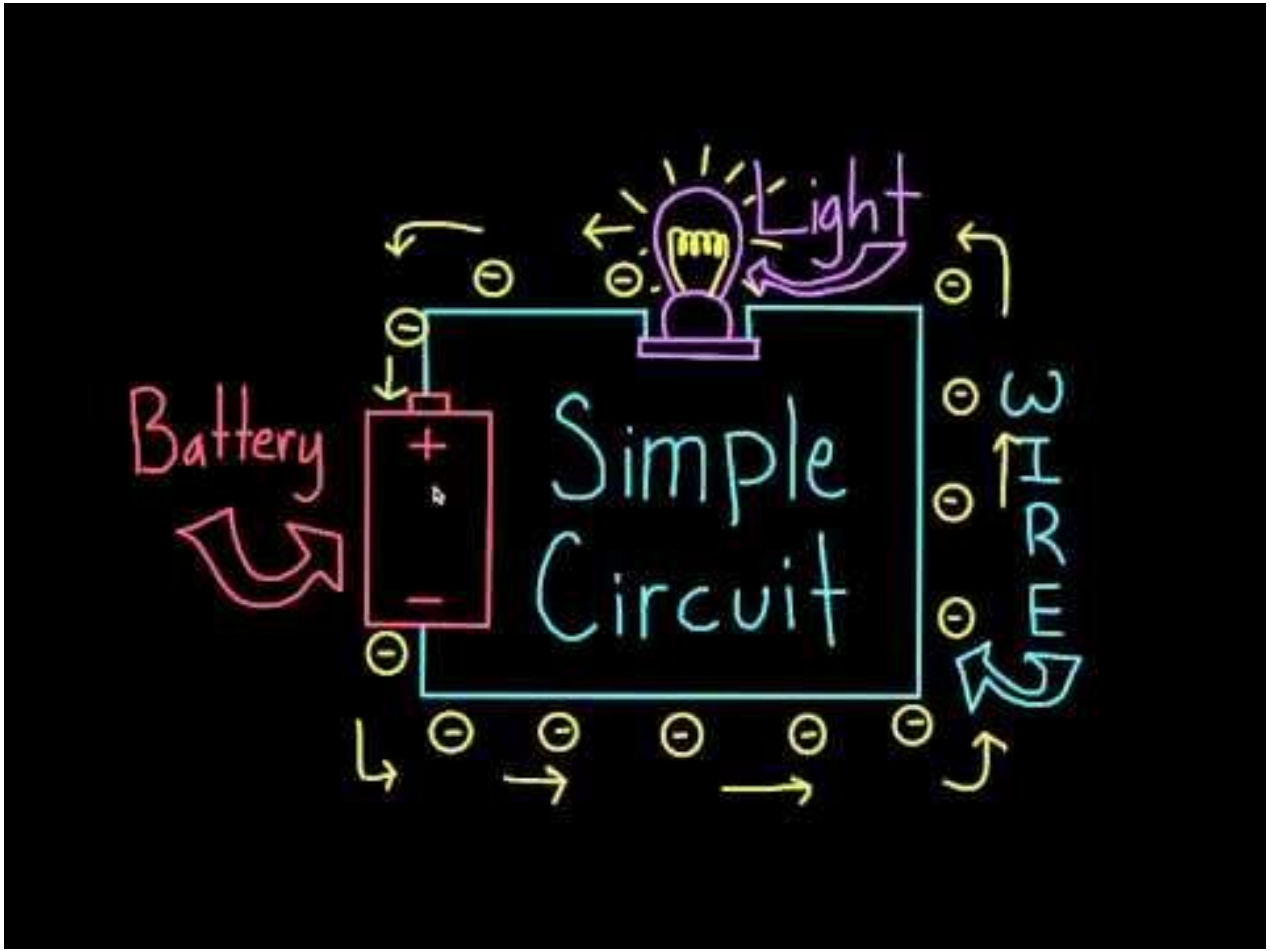
Browsers that work best with Tinkercad:

- Google Chrome version 50 (or newer), Safari 10 or newer, Microsoft Edge (Chromium)

Tinkercad Tutorials



Session 1: Circuits Basics

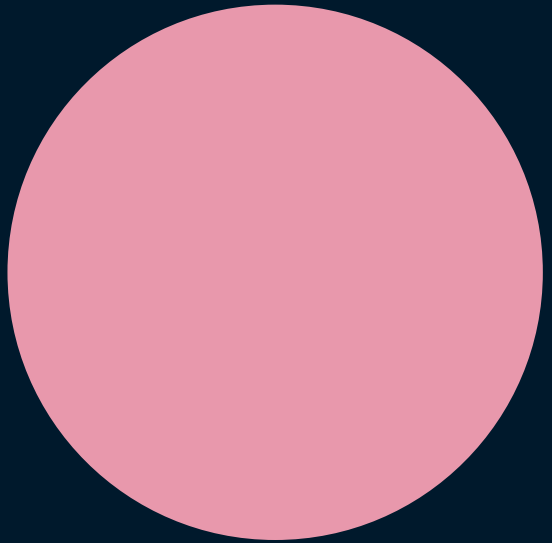

Light
Battery
Simple
Circuit
WIRE

Electronics Principles

Going microscopic

THE ELECTRON

Part of the ATOM



Acts like WATER

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moving electrons are **CURRENT**

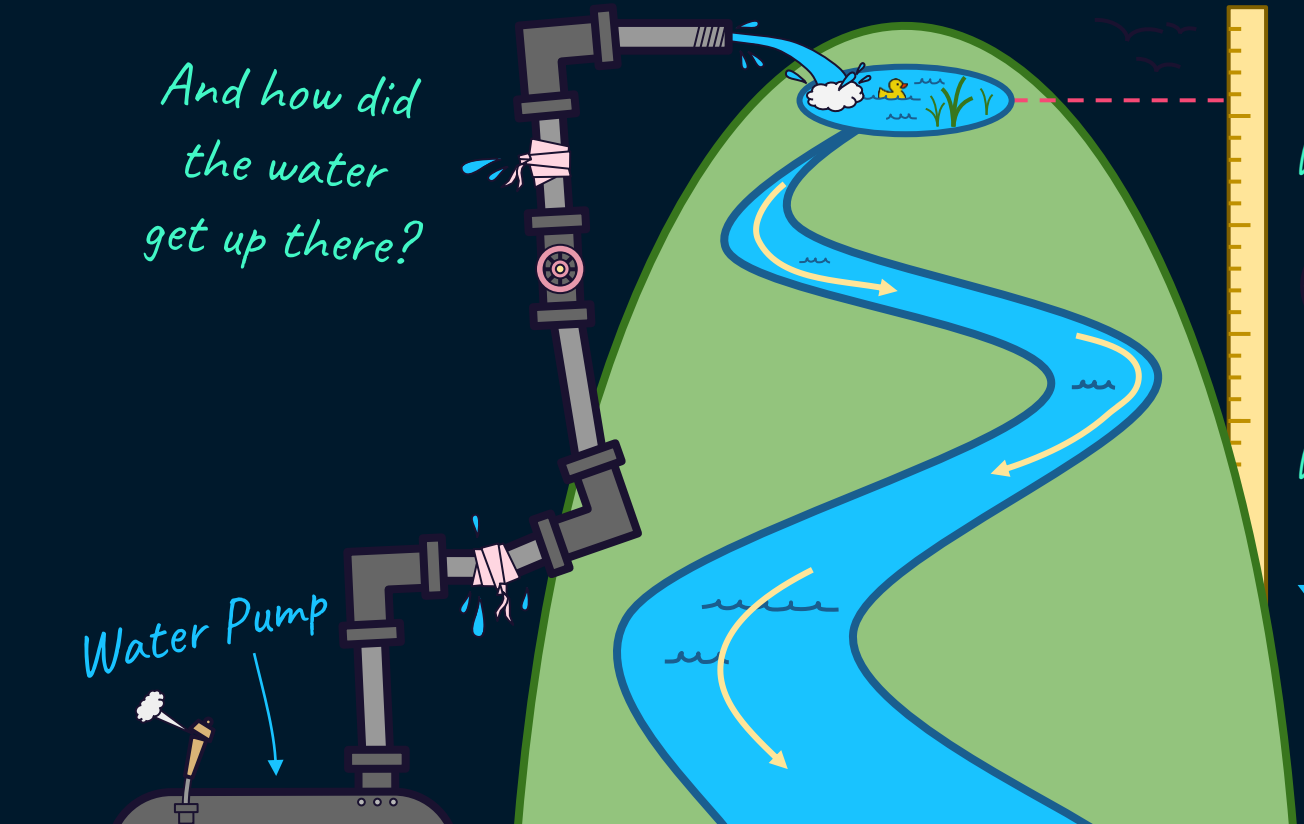
POTENTIAL motivates **CURRENT**

"voltage"

RESISTANCE restricts current

Electronics Principles

Electricity is like flowing water



What motivates the water to flow?

GPE GRAVITATIONAL POTENTIAL ENERGY + WORK DONE BY PUMP W

We call the water flow "Current"

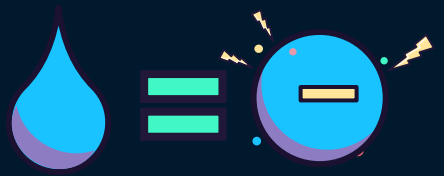
CURRENT (FLOW RATE)

The taller the hill, the greater the potential

Electronics Principles

Water flow is like current

So, the analogy is:



But now, gravity's not the driving force...

GPE — ELECTRICAL GRAVITATIONAL POTENTIAL ENERGY — VOLTAGE V

"

And we still call it Current!

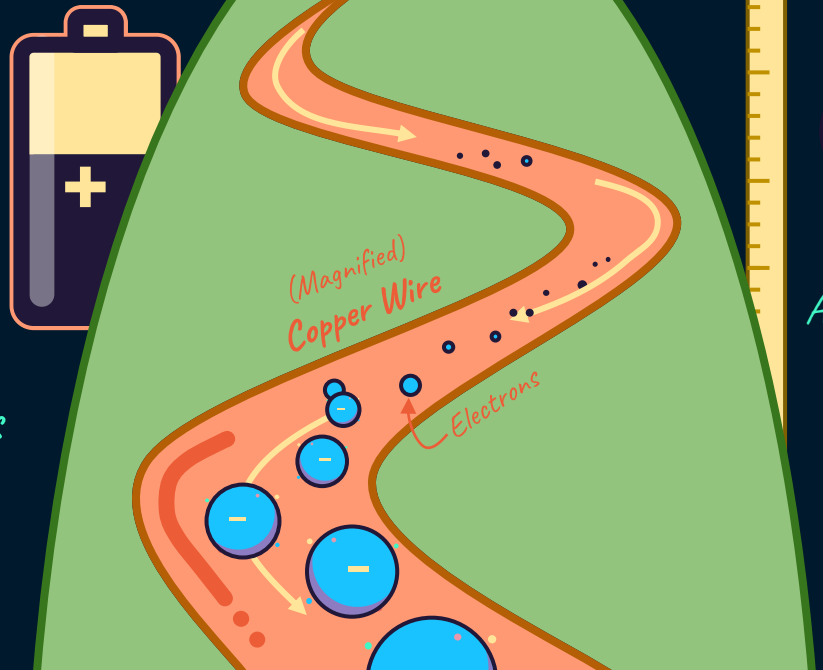
CURRENT (FLOW RATE) I

...we just use a different symbol, "I"

(it's French! Andre Ampere)

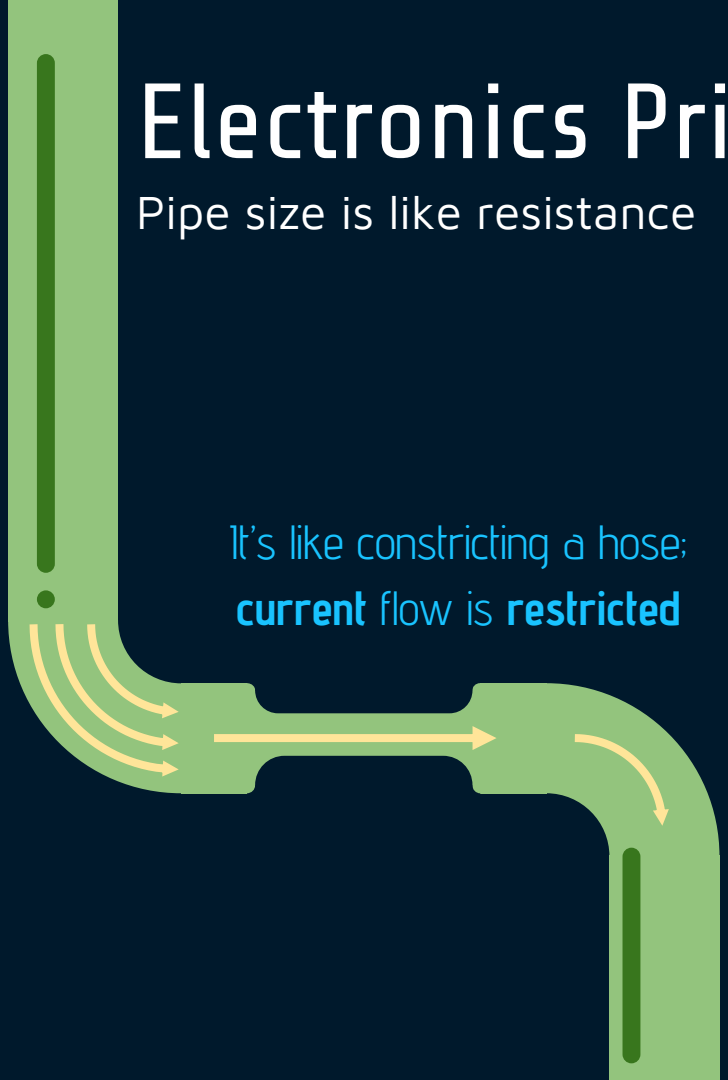
Voltage is the Electro-Motive Force...

...the voltage from a **Battery** motivates electrical current

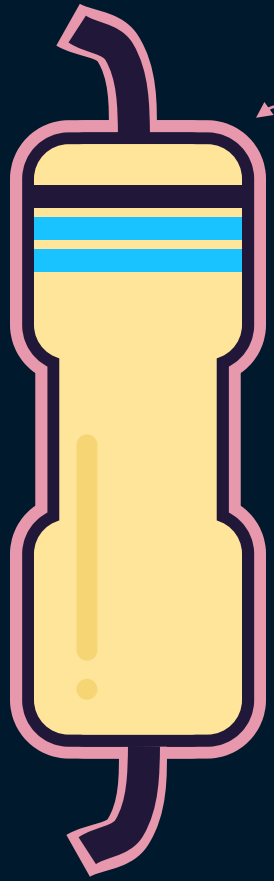


Electronics Principles

Pipe size is like resistance



It's like constricting a hose;
current flow is **restricted**



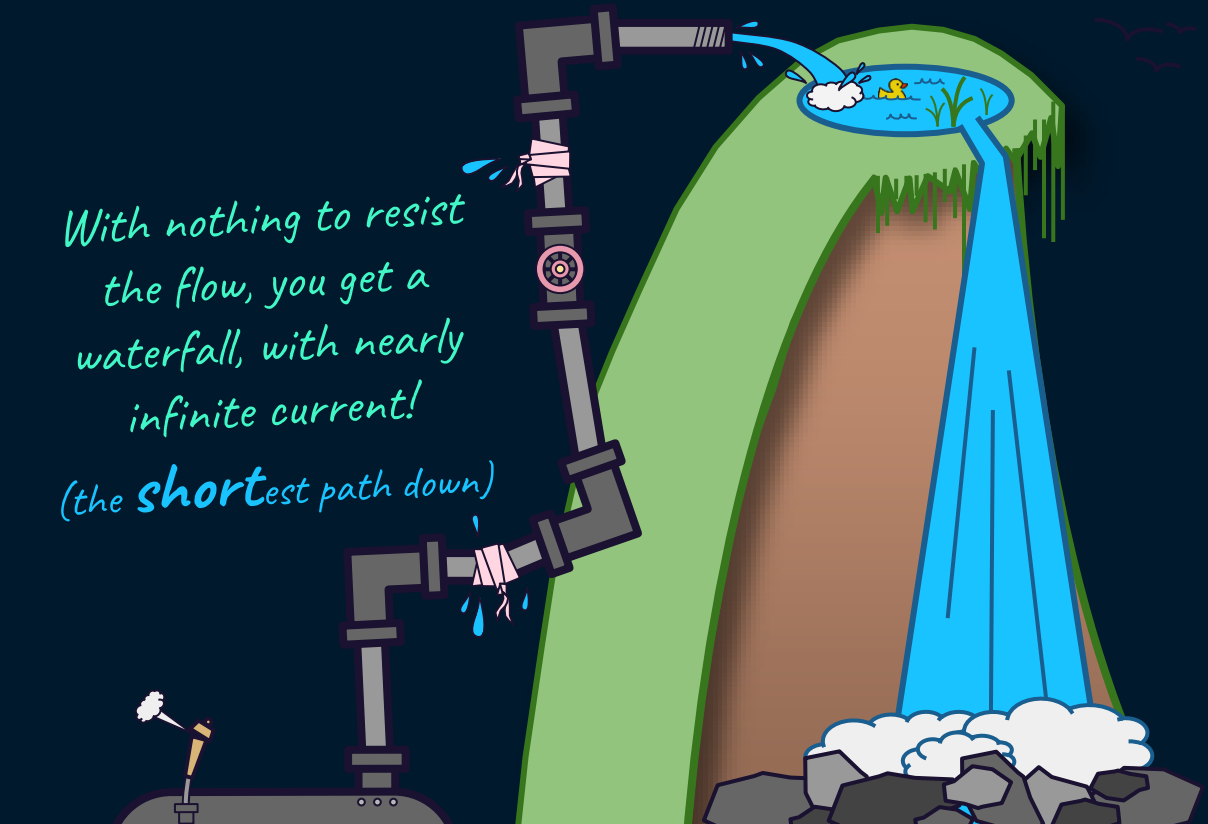
R

RESISTANCE

Resistance changes electrical energy into heat or work (it reduces **voltage**)

Electronics Principles

The resistance waterfall



With nothing to resist the flow, you get a waterfall, with nearly infinite current!

(the **short**est path down)

Resistors restrict Current...

...let's imagine the case of NO resistance...

Electronics Principles

Short circuits

In the context of electronics, it's not so pretty...

Without resistance, we have a

SHORTcut

from + to − on the battery...

This "Short Circuit" allows

UNLIMITED CURRENT

to flow, which can damage electronics

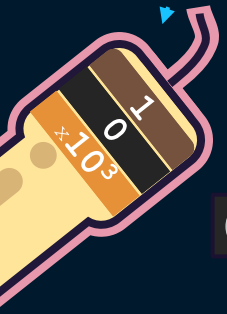
Electronics Principles

When we DO introduce resistance, think of it as a water wheel!

Resistance is measured in

Ohms (Ω)

The size of a resistor is designated by its bands

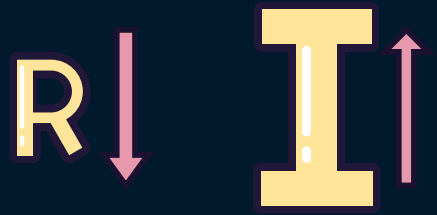


10k

Ohms (Ω)

A smaller (faster) wheel, passes more water...

Less Resistance = More Flow



Notice...
Voltage (hill height) isn't necessarily affected...

Electronics Principles

Ohm's Law
is a math-based relationship that describes how a circuit will behave

$$V = I \times R$$

Volts (V) | Current Amps (A) | Resistance Ohms (Ω)

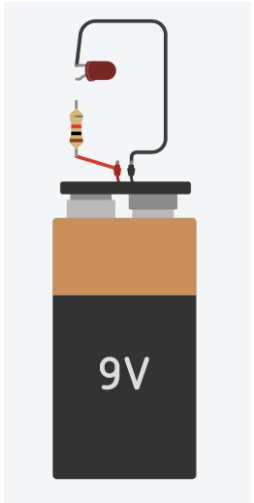
Let's summarize... (so far)

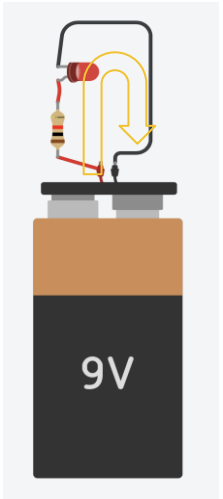
V = VOLTAGE — PUMP, HILL HEIGHT, BATTERY

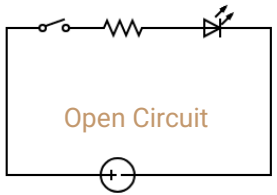
I = CURRENT — FLOW RATE, ELECTRONS

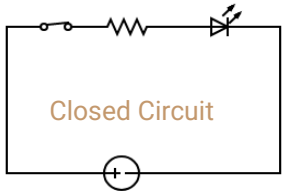
R = RESISTANCE — WATER WHEEL, RESISTOR

Electrical Circuits Explained









- Electrical circuits contain **conductive paths for current (or electrons) to flow:**
  - Open loop = current can’t flow
  - Closed loop = current can flow

- Circuits enable us to turn lights on/off, computers to work, and more!

Series & Parallel Circuits

What is series?

"Series" means components are hooked up one after another.

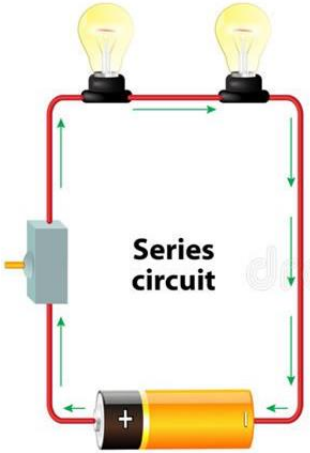
What is parallel?

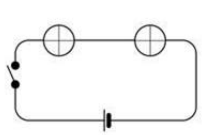
"Parallel means components are hooked up side by side.

Let's see an example:

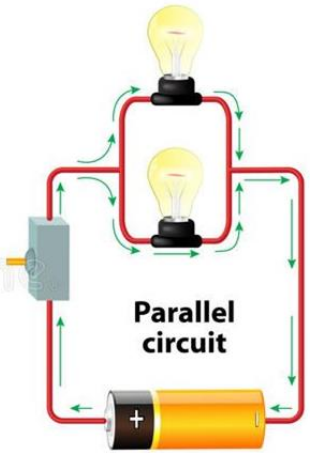
Current is what makes a light bulb glow!

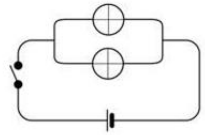
More current = More light





A series circuit decreases the current.





A parallel circuit increases the current.

Session 2: Circuits Simulator

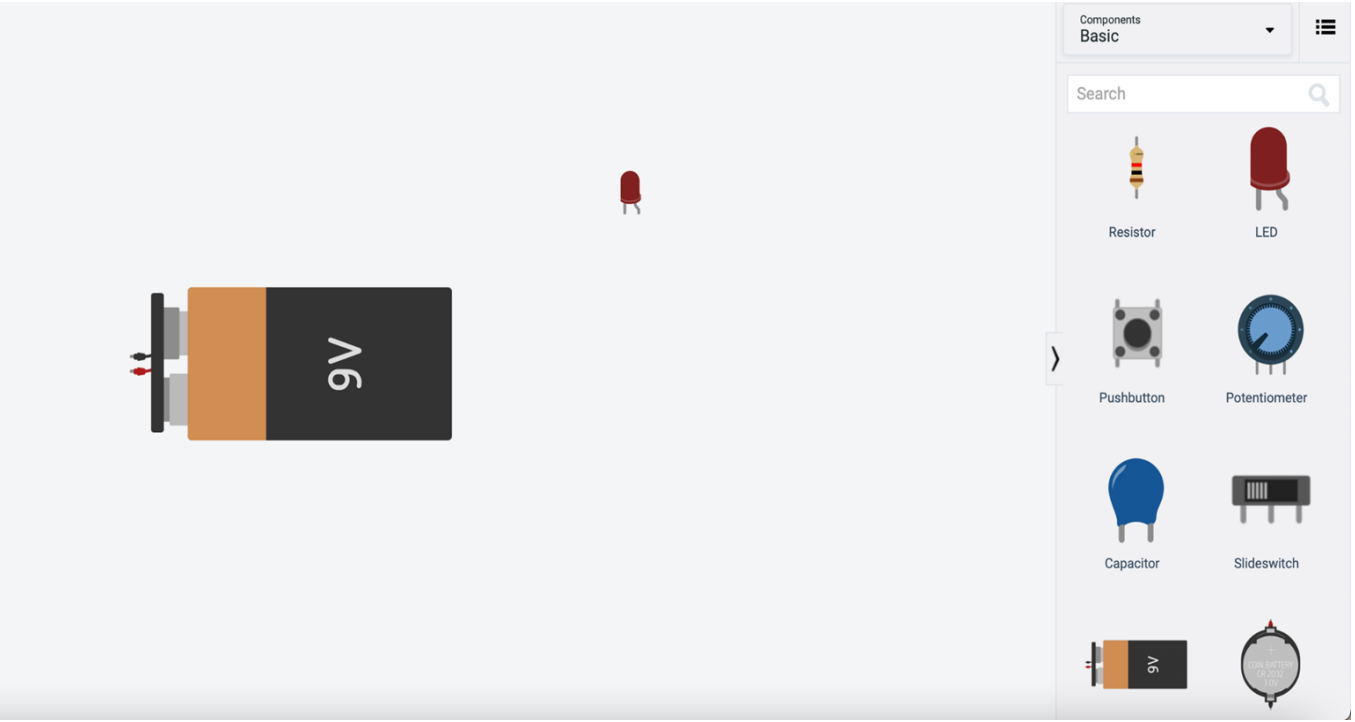
Tinkercad Circuit Simulator

Instructions:

1. Login to**Tinkercad.com**> **Designs>Circuits>Create**
1. Follow along to learn to use the Tinkercad Circuit Simulator interface

Getting the Gear

1. Search for 9V battery
2. Click and drag into workspace
3. Find LED and repeat!

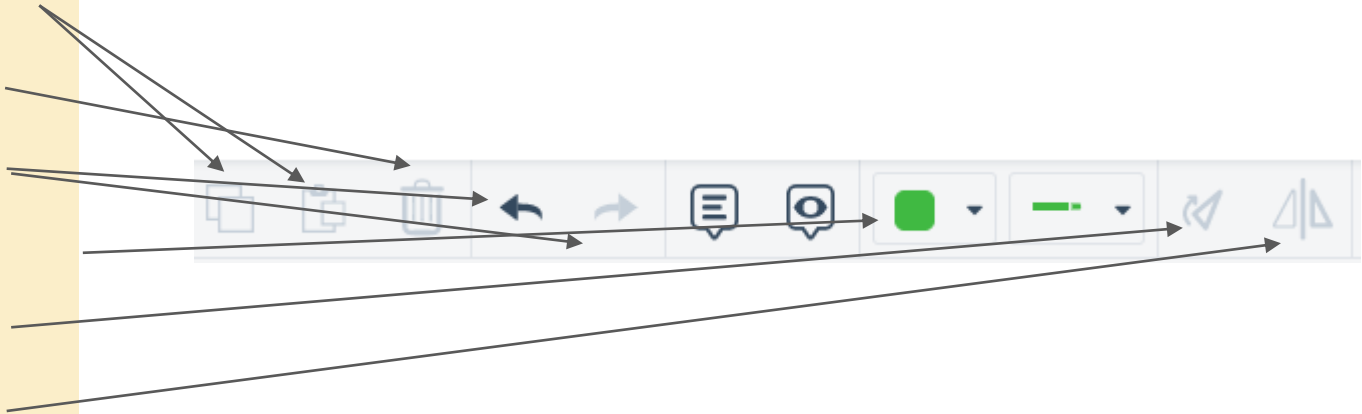


We’re going to use the battery to power the LED in our circuit.

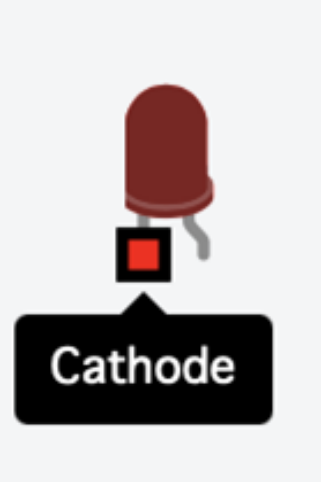
Using the Tools

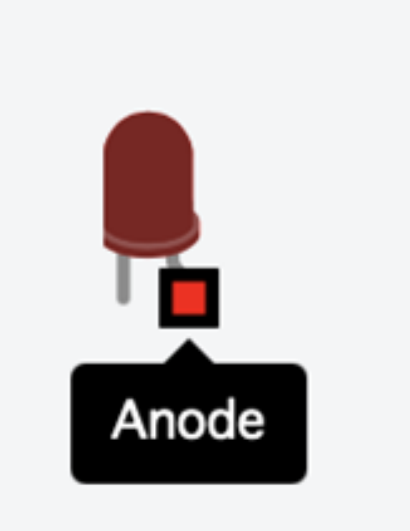
We can use the toolbar at the top left for:

- Copying & Pasting
- Deleting
- Undo/Redo
- Changing wire colors
- Rotating
- Flipping



Wiring LEDs





If you forget which is which, you can hover over the ends to see anode/cathode!

LEDs have two sides, and it matters which is which.

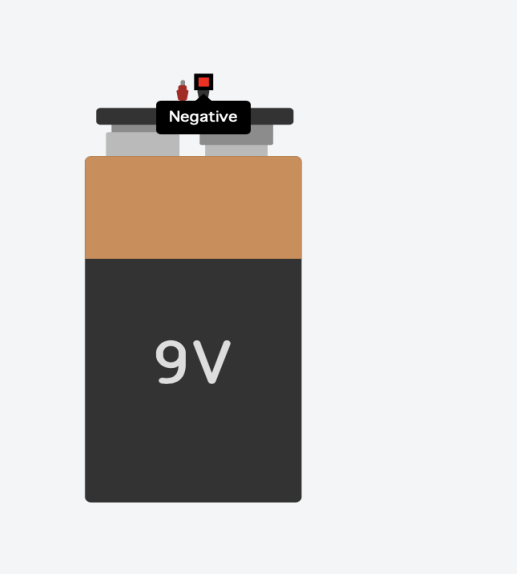
- The *anode* is the longer, bent terminal
- The *anode* connects to positive (+) power
- The *cathode* is the shorter, straight terminal
- The *cathode* connects to negative (-) power

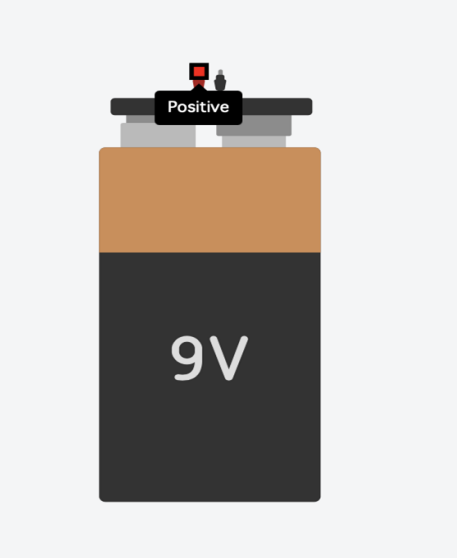
Wiring the Battery

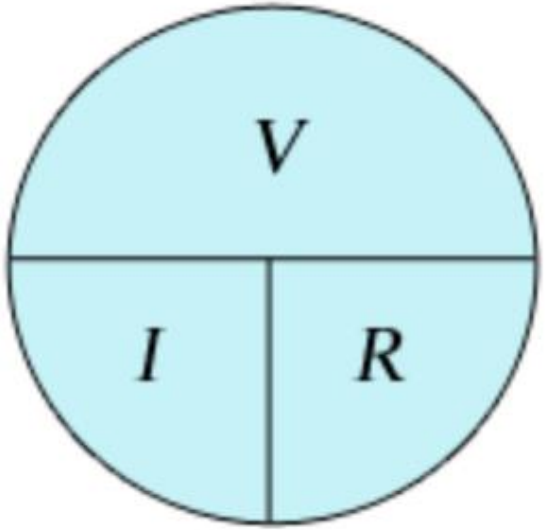
The battery has positive and negative terminals just like the LEDs.

Traditionally, **RED** is **positive** and **BLACK** is **negative**

If you forget, you can hover over the terminals to see which is which!







$V = IR$

$R = V/I$

$I = V/R$

Circuits Vocab

V = the voltage in an electric circuit is a measure of the amount of electrical potential energy per charge between two points in the circuit.

I = (Current in Ampere) the flow of electrons in an electric circuit.

R = Resistance is the opposition to current flow. the greater the electrical resistance for a given voltage, the less electric current will exist.

Ohm’s Law: Ohm's Law relates the quantities of voltage, electric current, and resistance in one easy-to-use equation

Building the Circuit

STEP 1:

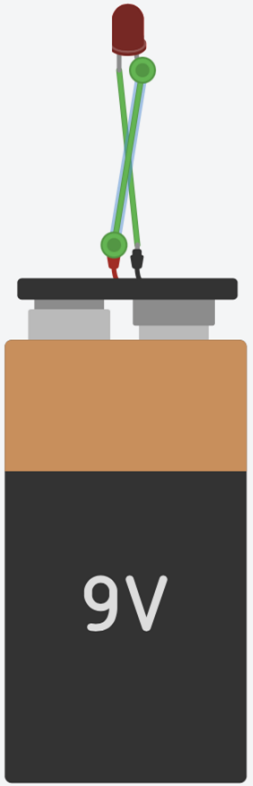
Click on the negative terminal of the battery.

Drag the mouse over to the *cathode* of the LED and click.

Bonus:

Color the wire BLACK so you remember that its negative!

Building the Circuit



STEP 2:

Click on the positive terminal of the battery.

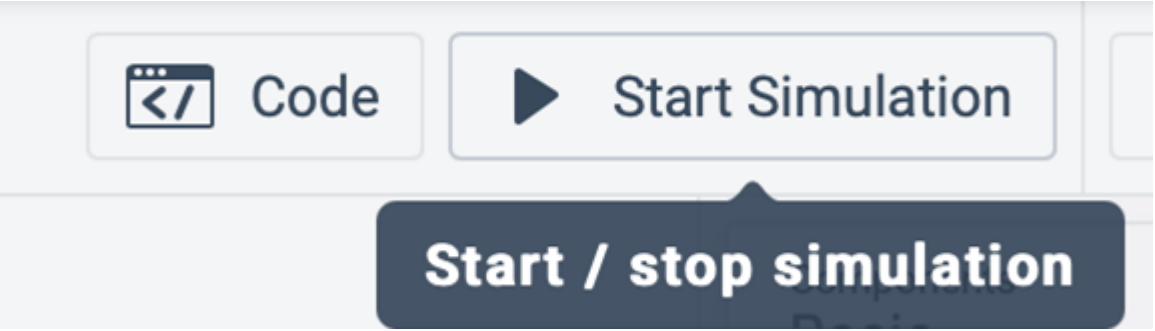
Drag the mouse over to the *anode* of the LED

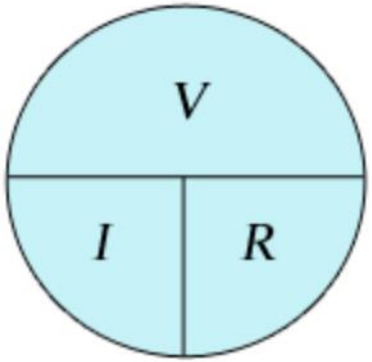
Bonus:
Color the wire RED so you remember that its positive!

Running the Simulation

Find `Start Simulation` in the top right.

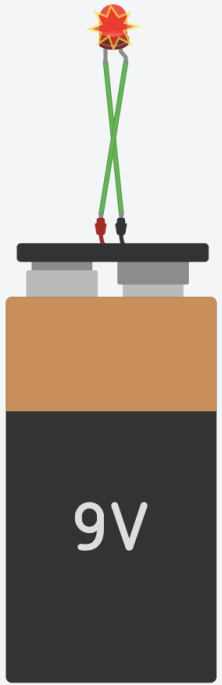
Click it to see our circuit in action!





$V = IR$
$R = V/I$
$I = V/R$

Ohm’s Law Table



Uh Oh! Troubleshooting

We broke our LED! Remember before how current meant more light? Well more current can also mean too much heat.

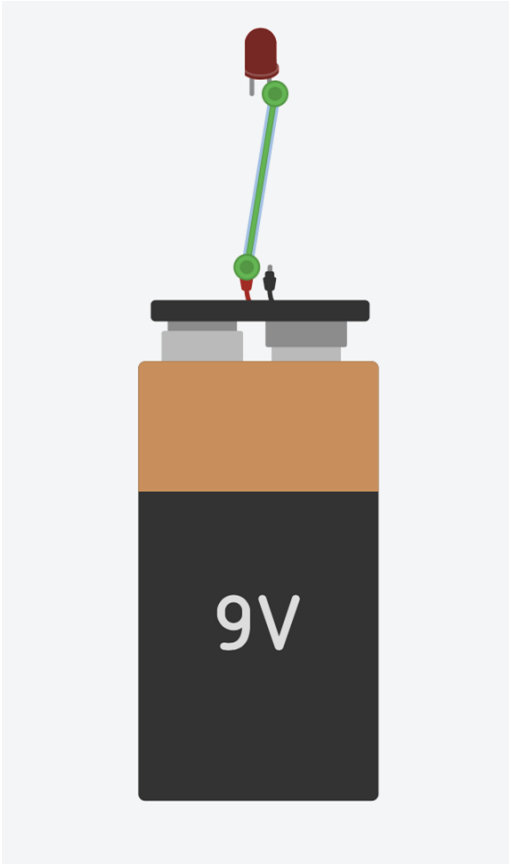
We supplied our LED with too much current, and it got too hot and exploded!

Remember ohm’s law? We can limit this current with resistance.

Problem Solving

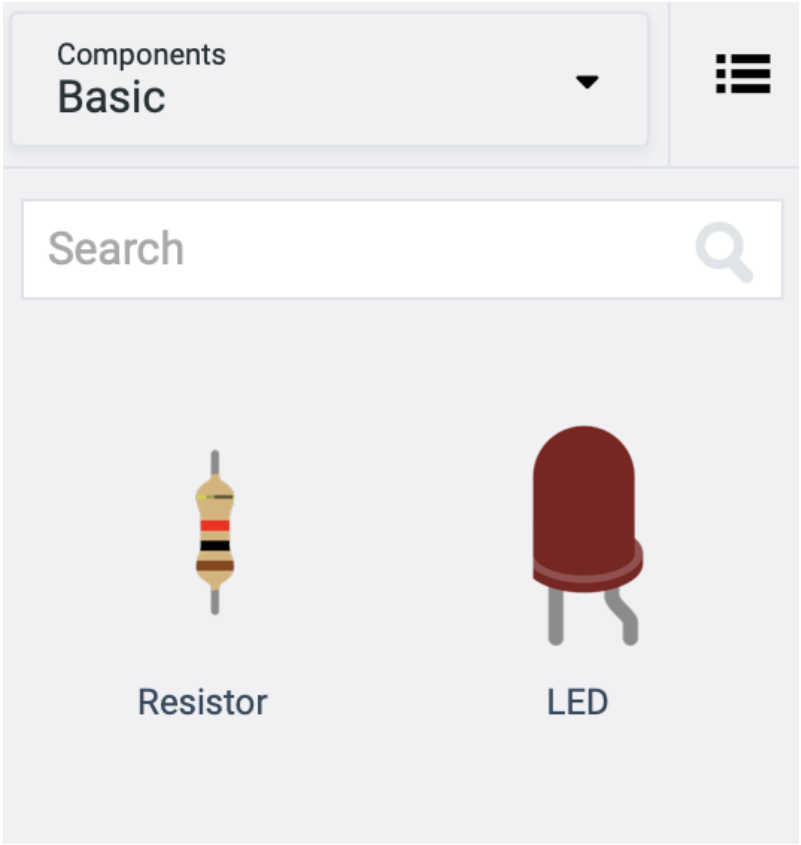
Let’s fix our circuit!

Just like before, click on the terminal of the battery, then click on the terminal of the LED to make a connection



Bonus:
Who can name which LED terminal we hooked up?

Getting More Gear



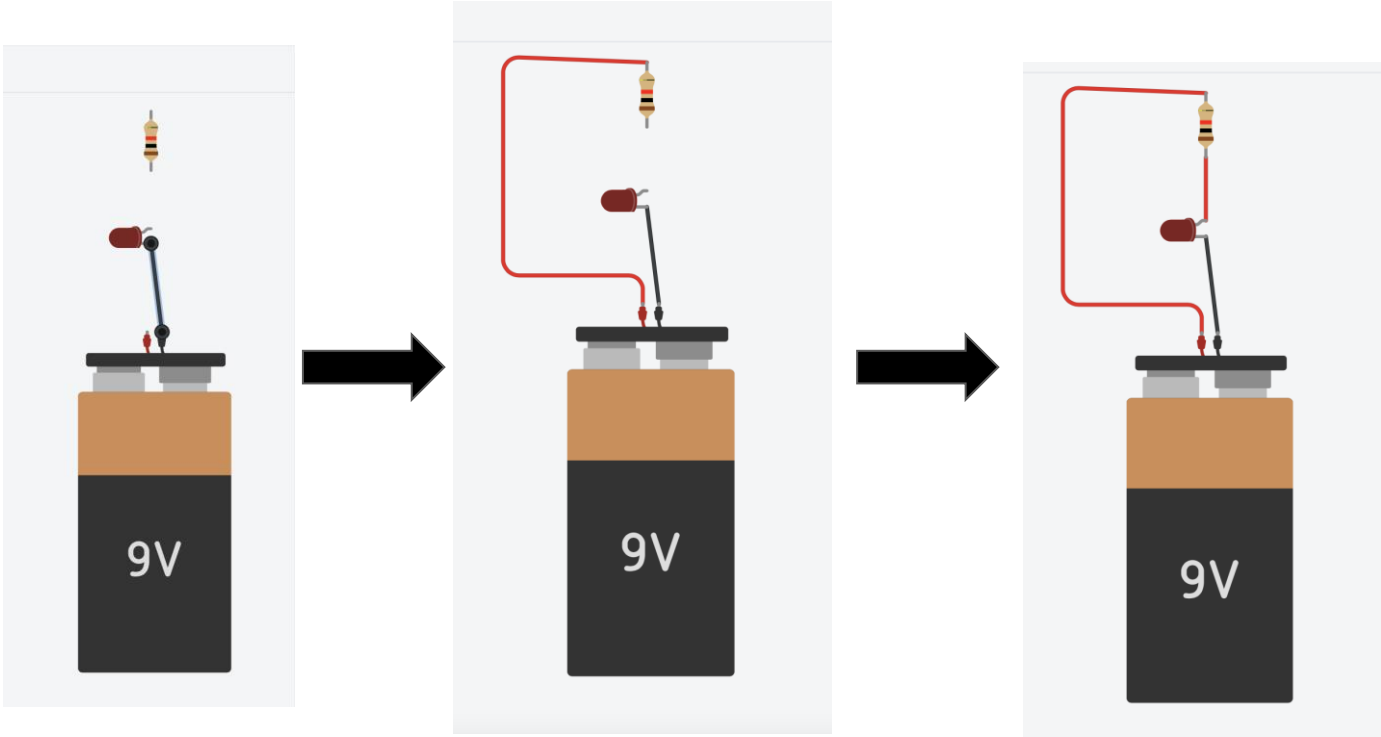
Search for a resistor in the search menu.

Click, drag, and click to drop the resistor into our workspace.

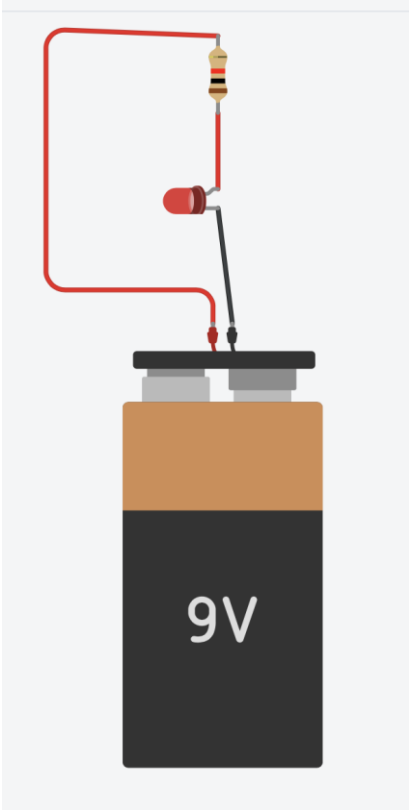
Building the Circuit Part II

Now we want to put the resistor in *series* with the LED.

To do so, we need a complete loop that travels from the positive battery end, to the resistor, out of the resistor to the *anode* of the LED, and finally back to the negative end of the battery.



Test it Out!



Find `Start Simulation` in the top right.

Click it to see our circuit in action!

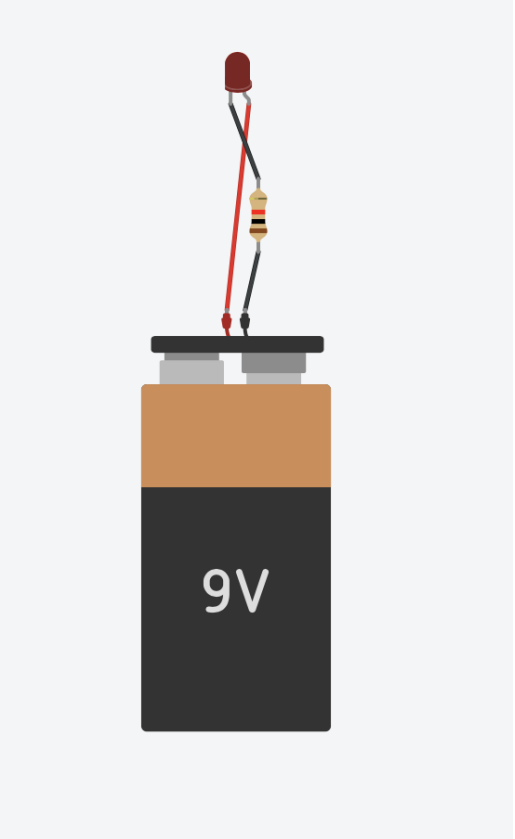
Viola! We have successfully created an LED circuit!

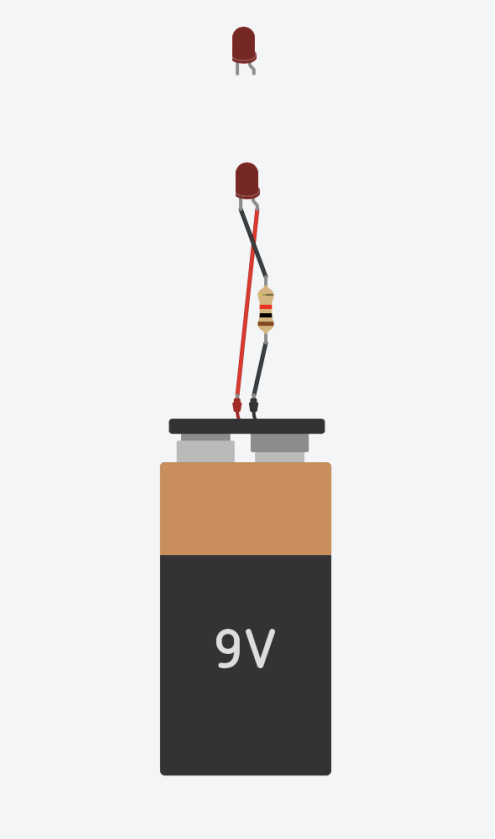
Parallel Circuit

We’re going to make another circuit, this time with LEDs in parallel.

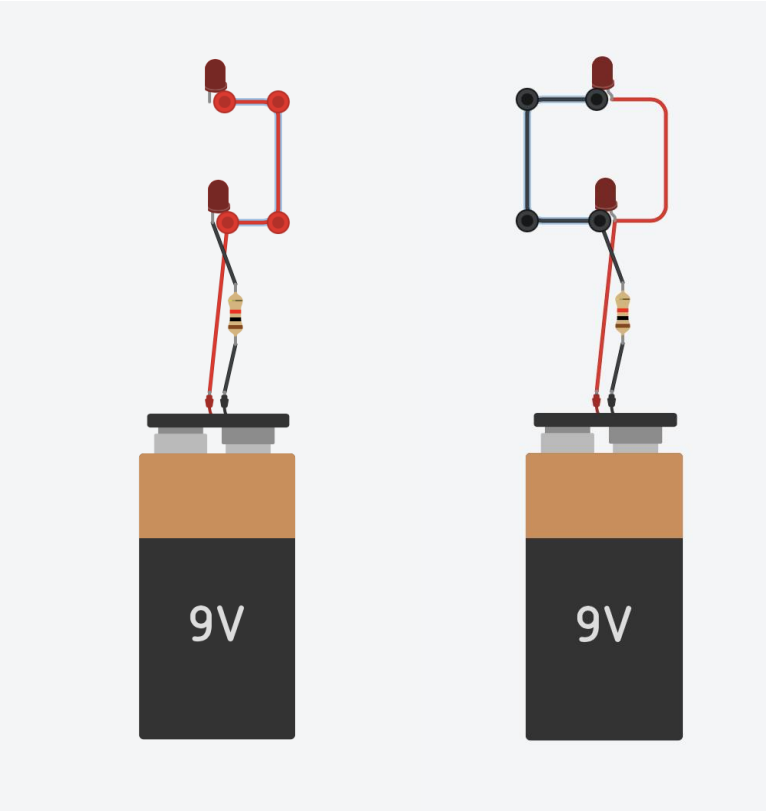
To start, let’s recreate our simple series circuit.

On top of this, let’s grab another LED





Parallel Circuit



Now we'll see why coloring our wires was important.

To make a correct parallel circuit, we need our *anodes* of our LEDs to be connected, and the *cathodes* to be connected.

Exercise:

Trace your finger from negative to positive of the battery, you should be able to find two paths

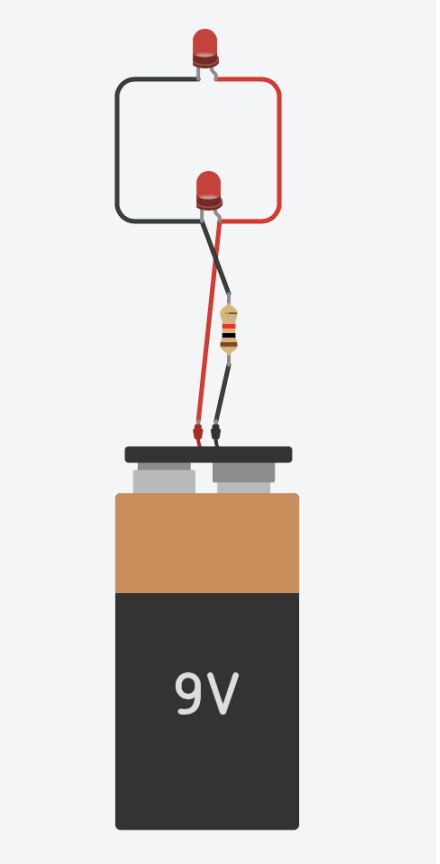
Parallel Circuit

Notice that the two LEDs are both as bright as the single series LED was.

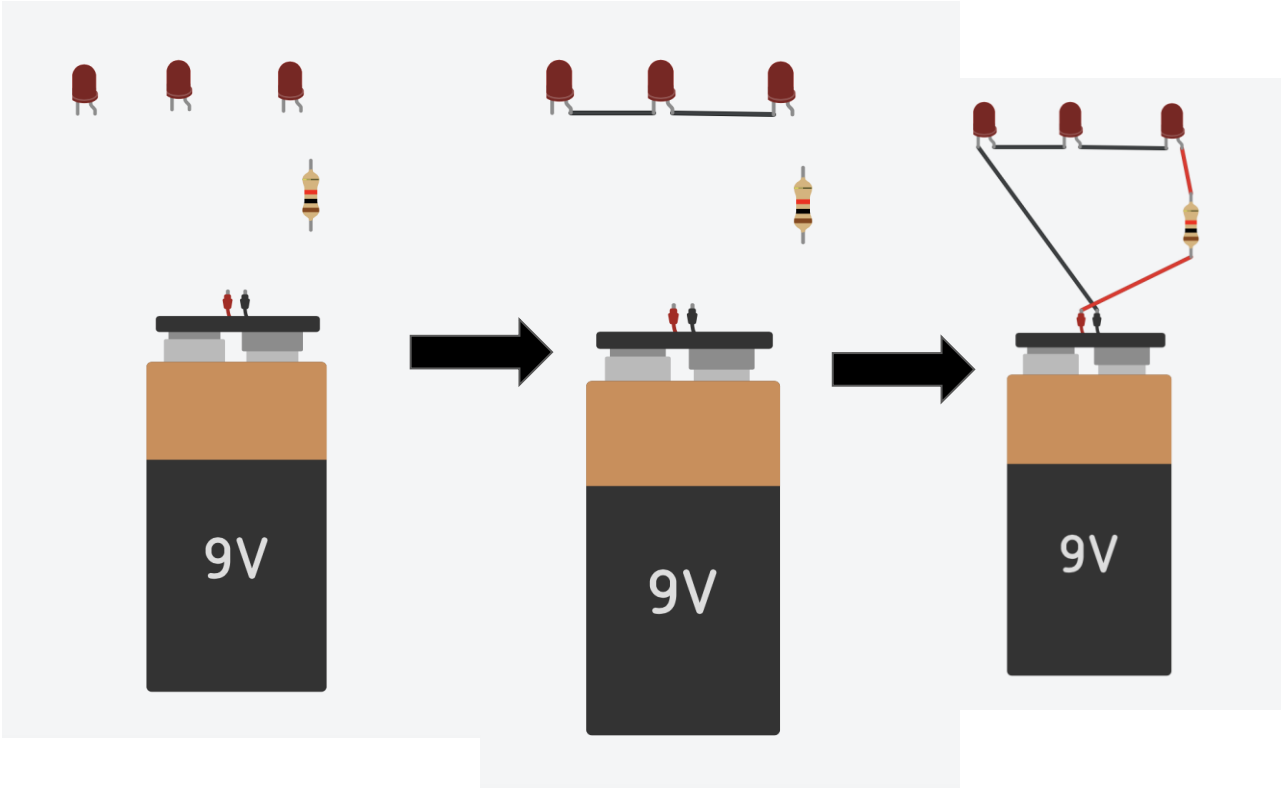
Recall that more current is more brightness, and with unchanging resistance more current means more voltage. (Ohm's law! V = IR)

Now, the LEDs have to be the same brightness because the voltage across them is the same! The voltage from the battery has to be 9V, and each LED connects the two terminals of the battery together.

If the negative end of the battery is 0V, and the positive terminal is 9V, then the voltage across both LEDs is 9V!



Series Circuit



Grab three LEDs, a resistor, and a battery.

Then connect all three LEDs (anode to cathode).

Now connect the LED string to the “ground” (negative battery terminal) and the resistor to the positive terminal.

Exercise:

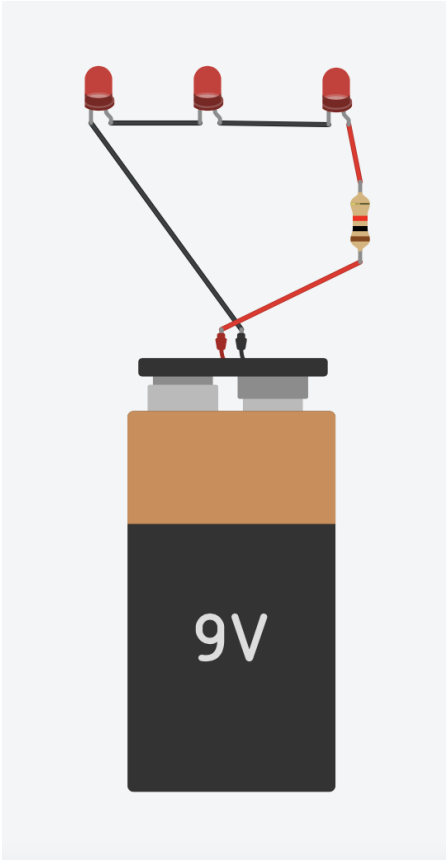
Trace your finger from negative to positive of the battery, you should only be able to find one unbroken path

Series Circuit

We've completed our series circuit. Notice how all the components form one unbroken loop.

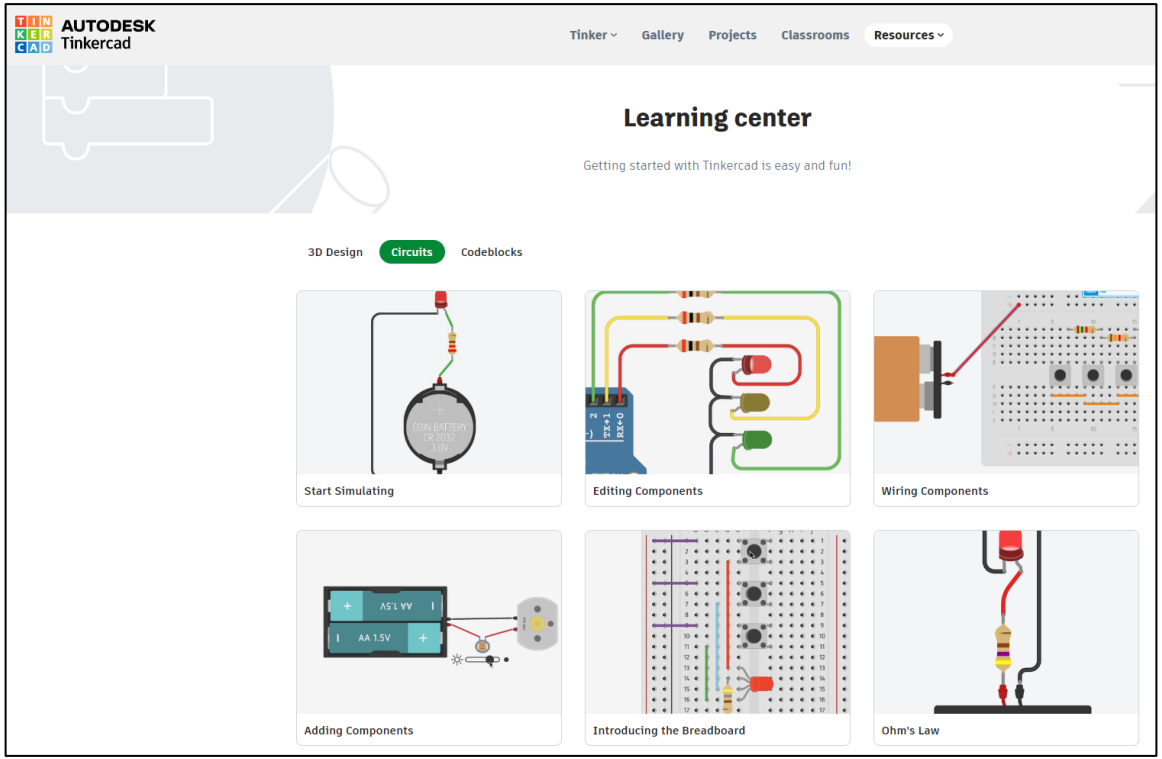
With our parallel circuit, each loop was given 9V across it. This is still true, however now that voltage is shared between 3 LEDs instead of 1.

This makes the LEDs dimmer than those of the parallel circuit.



Create Your Own Tinkercad Circuit

Choose a Tinkercad Circuits Tutorial



It’s YOUR turn to get creative with circuits!

Instructions:

1. Choose a Learning Center “Circuits” project
2. Get tinkering! Use **“Basic Components”**
    - Batteries
    - LEDs
    - Resistors
    - and more
3. Share your creation!

Reminders:

- Wire the components in a closed loop
- LEDs need current-limiting resistors
    - Anode to positive (red)
    - Cathode to negative (black)
- Click on **“Start Simulation”** to test your circuit
- Back arrow or “Control Z” to undo
- Click on the Tinkercad “waffle box” icon to get back to the homepage
- Ask for help if you get stuck!

Circuits Review

1. Take a screenshot of your circuit design.
2. How does your circuit work?
3. What components did you use?
4. What is your power source (type and number of batteries)?
5. How many LEDs did you use? If more than one LED, are they connected in series, parallel, or both?
6. What ideas do you have to change up your circuit?

Tinkercad Circuits & EV Motor Workshop

Part 2: Motor Circuit Simulator

& Build an Electric Motor Circuit

ASPIRE
NSF Engineering Research Center

Engineering & Applied Science
UNIVERSITY OF COLORADO BOULDER

INTEGRATED TEACHING & LEARNING
Program and Laboratory

What You'll Need!

Computer, Mouse & Internet Connection

Microsoft Windows 10, Apple OSX10.10, or Chrome OS on Chromebooks

+

TinkerCAD Account

Go to https://www.tinkercad.com

Browsers that work best with Tinkercad:

- Google Chrome version 50 (or newer), Safari 10 or newer, Microsoft Edge (Chromium)

Review Electronics Principles

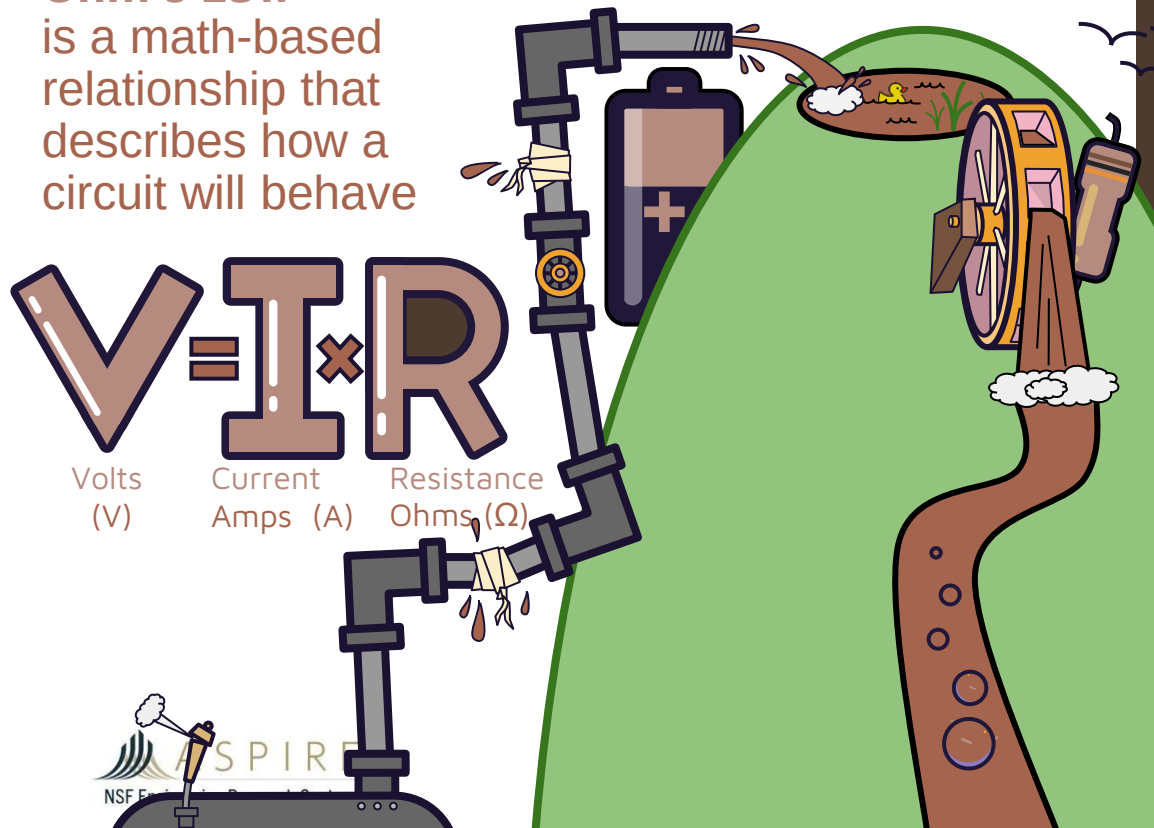
Let's summarize...

(so far)

Ohm's Law
is a math-based relationship that describes how a circuit will behave

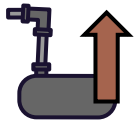
$V = I \times R$

Volts (V) | Current Amps (A) | Resistance Ohms (Ω)



$V =$

VOLTAGE



PUMP

HILL HEIGHT

BATTERY

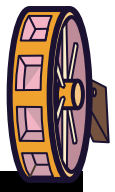
$I =$

CURRENT

FLOW RATE

ELECTRONS

$R =$



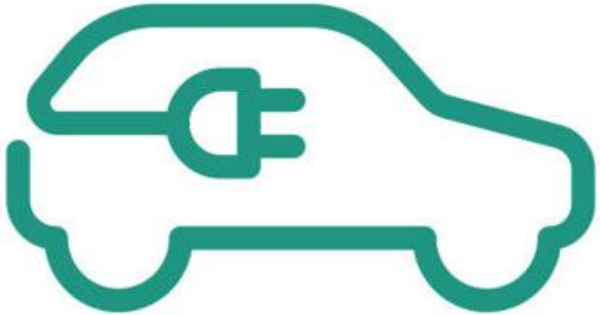
RESISTANCE - WATER WHEEL

RESISTOR

ASPIRE

NSF

INTEGRATED TEACHING & LEARNING Program and Laboratory



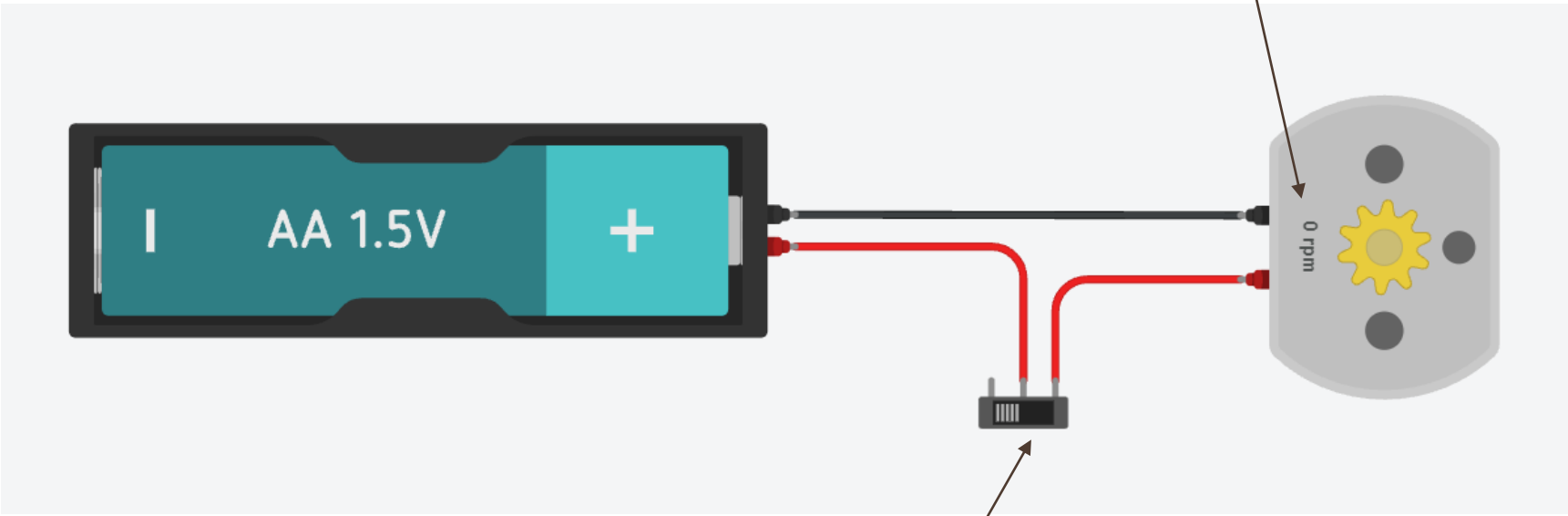
Session 3: Electric Motor Circuit Simulator

The goal today is to understand:

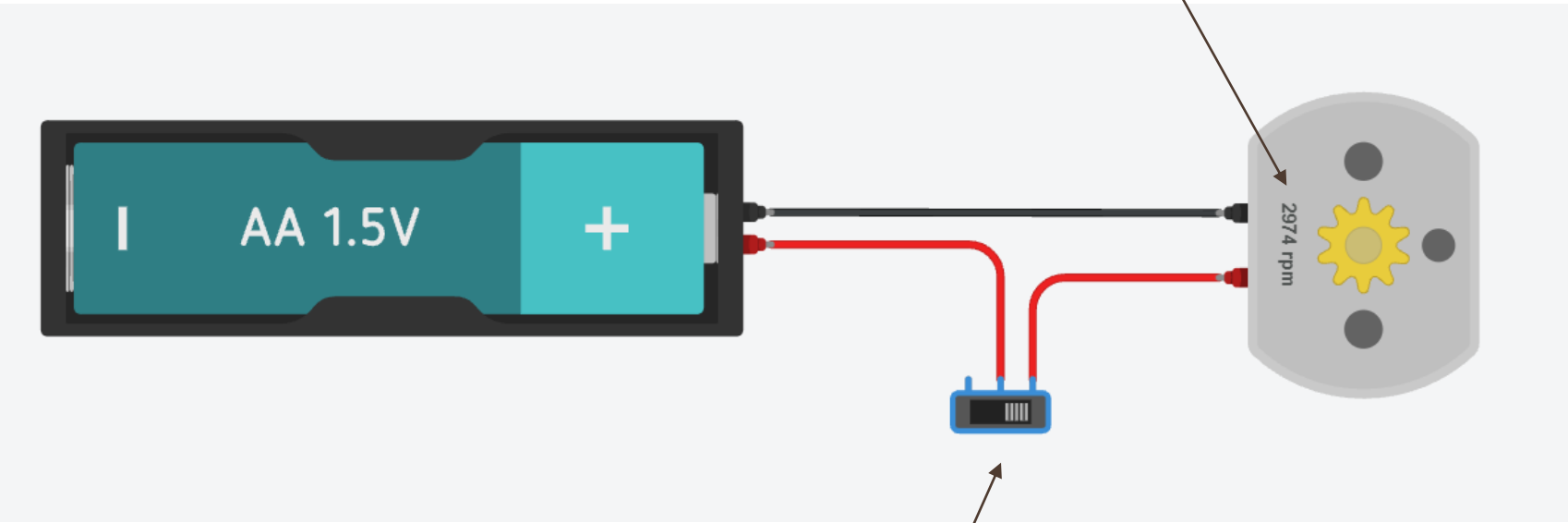
What makes an electric car go?

How can we model that?

Basic Electric Motor Circuit



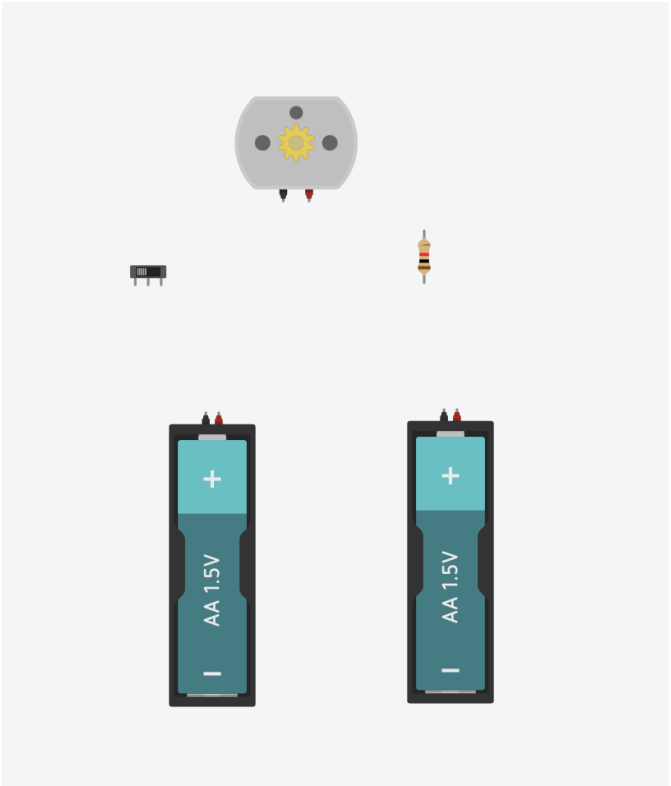
Basic Electric Motor Circuit



First, let's build a simulation of an electric motor

- Login to your Tinkercad account
- Follow along to build an electric motor circuit simulation!

Simple DC Motor



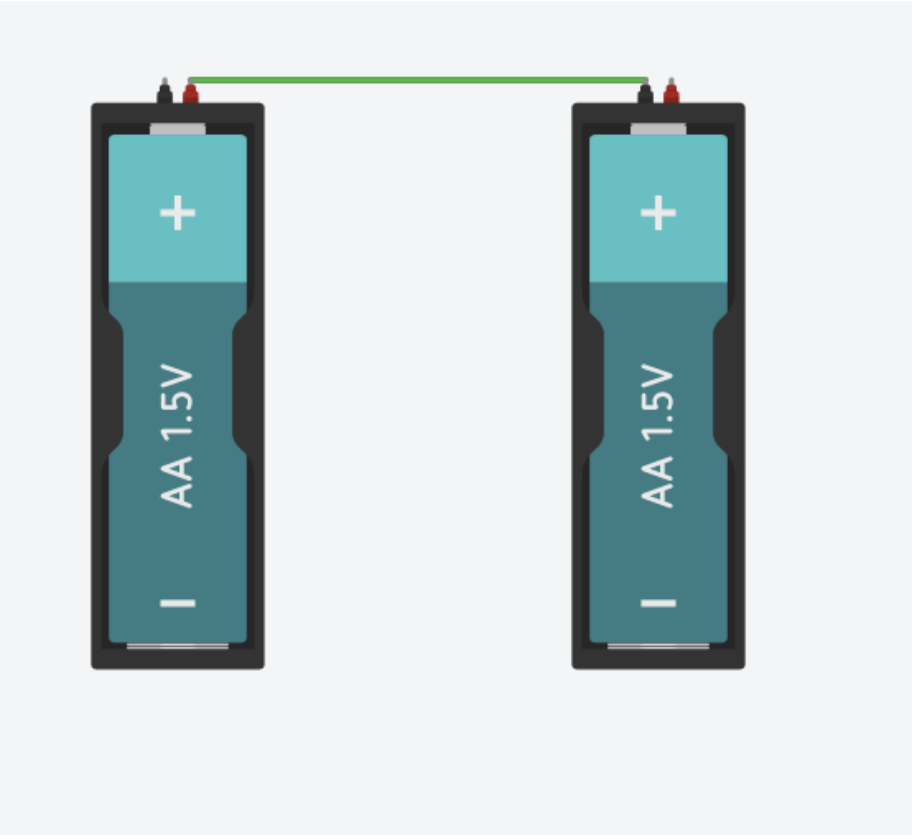
Tinkercad Circuit Simulator Supplies:

- Slide switch
- Resistor
- DC Motor
- 2 AA Batteries
- Wires

Vocab:

DC: Direct current – steady current, not switching back and forth

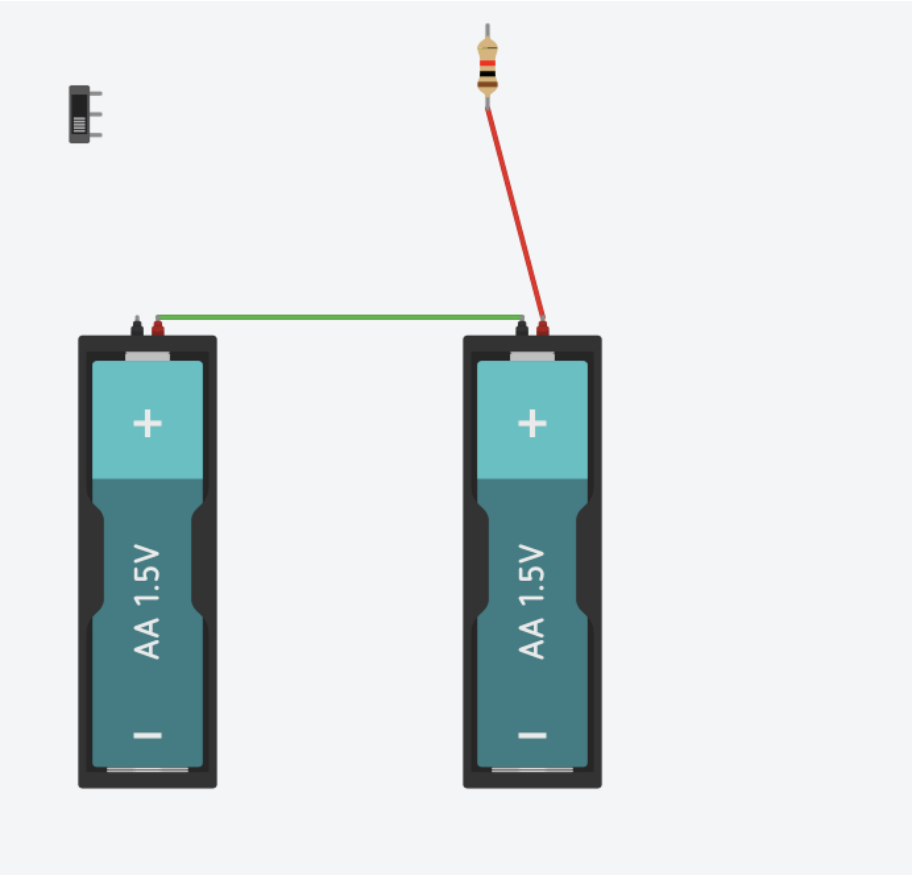
RPM: (Revolution per minute) – how many times the motor spins in one minute



Step 1:

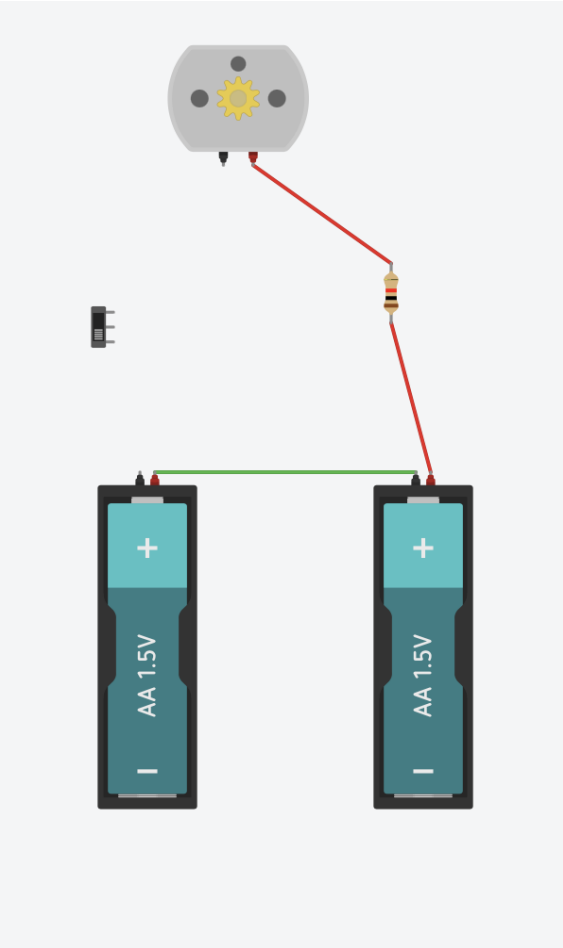
Connect the **POSITIVE** of one battery to the **NEGATIVE** of the next.

Like before, it's a good idea to color this *negative* wire black.



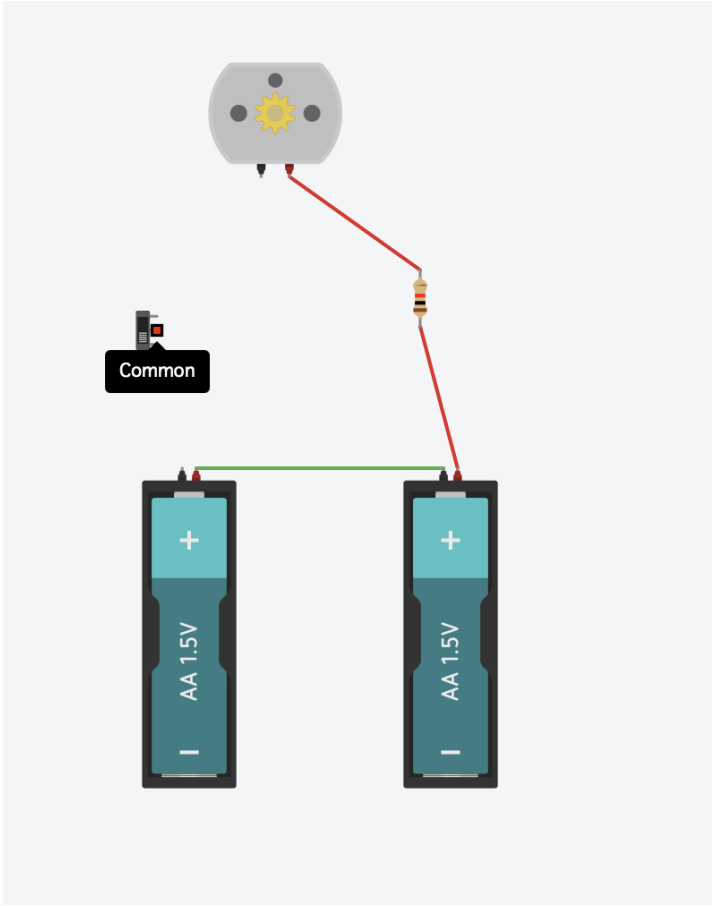
Step 2:

Connect the positive terminal of one of the AA batteries to the resistor.



Step 3:

Connect the resistor to the positive terminal of the motor (indicated by the red connection point).

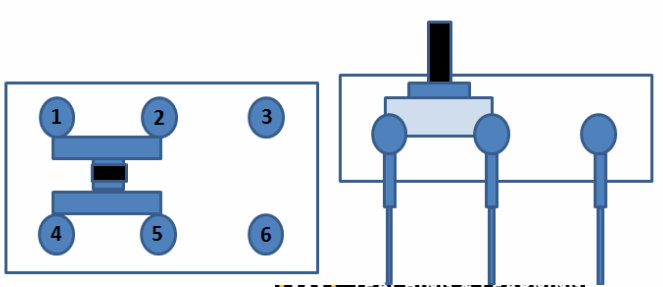


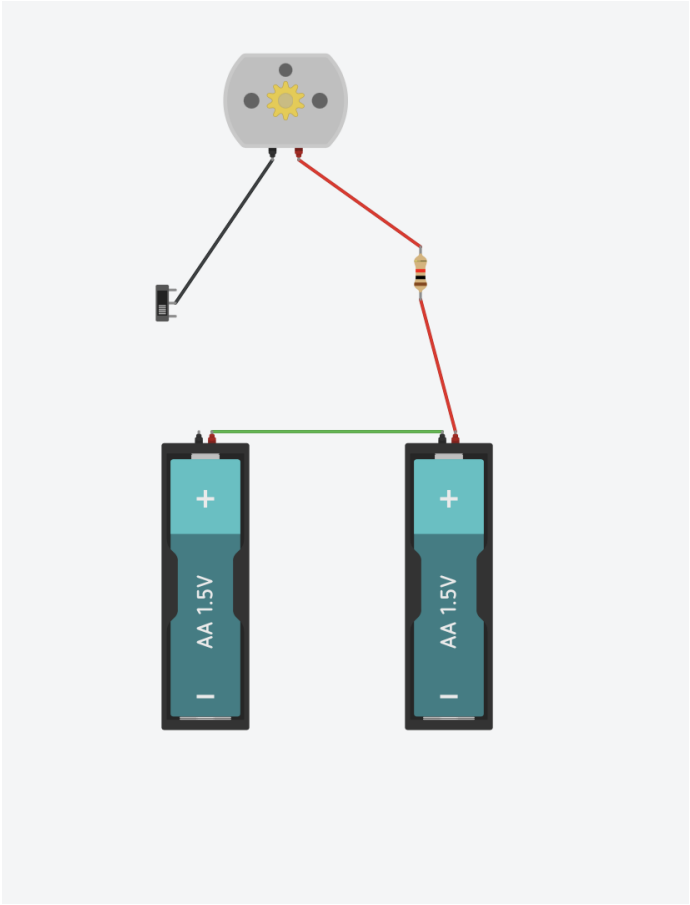
Step 4:

Slide switches have 3 terminals. The common, terminal 1, and terminal 2.

The switch will connect the common to the terminal on the side of the switch.

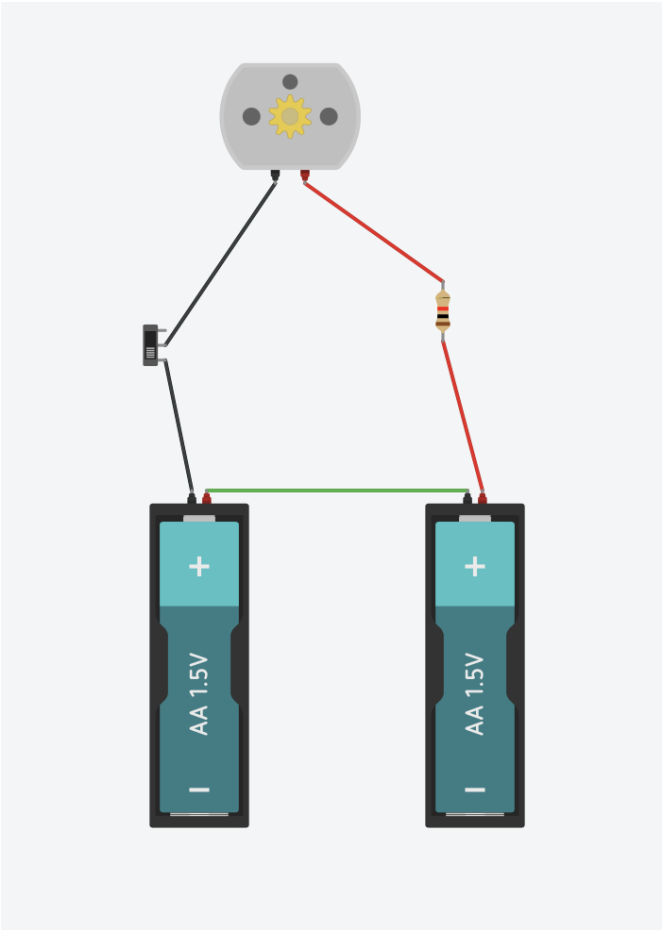
Push to the right, and the common connects to the rightmost pin.
Push left, and common connects to the leftmost pin.





Step 5:

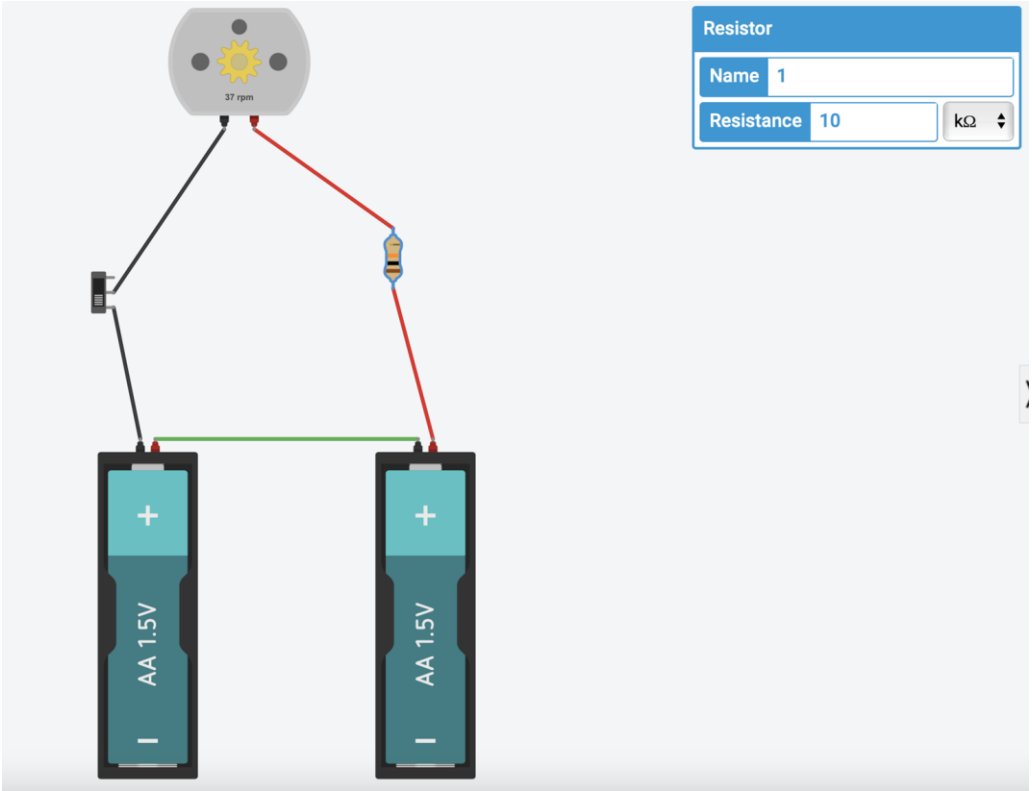
Connect the common to the negative (black terminal) of the DC motor



Step 6:

Finish the circuit by connecting terminal 1 to the negative wire of the battery.

What do you think will happen when we run the simulation? How about if we flip the switch?



Step 7:

In order to change the speed of the motor (RPM) play around with different values in the resistor.

Try to predict what different values will do to the RPM and think about why that might be the case.

Tips:

- Higher resistances = slower speeds (smaller RPMs)
- Lower resistances = higher speeds (higher RPMs)

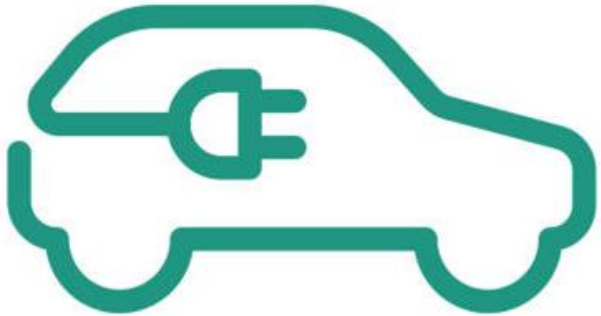
Circuits Review

1. Take a screenshot of your motor circuit design.
2. What components did you use?
3. How does your motor circuit work?
4. What is motor power source (type and number of batteries)?

Advanced Questions:

What would happen if you:

- connected the positive battery terminal to the negative motor terminal?
- connected the negative battery terminal to the positive motor terminal?

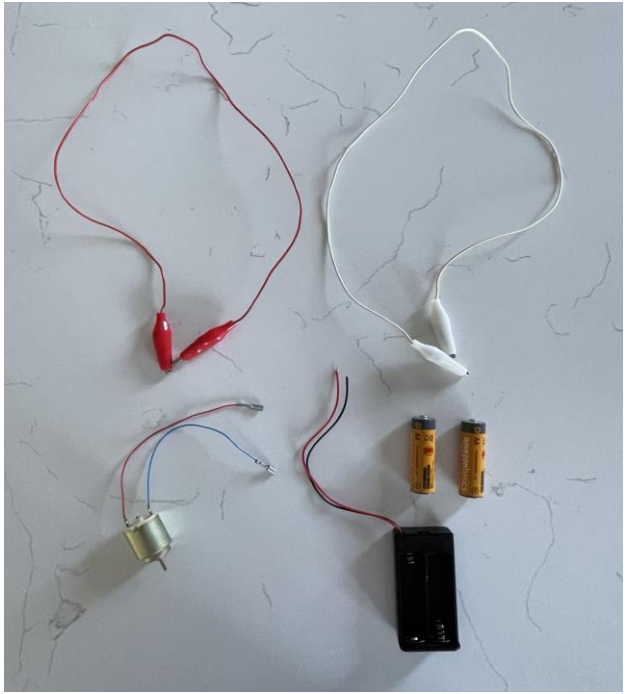


Session 4: Build an Electric Motor Circuit

Now, let’s build an electric motor circuit!

Motor Components:

- 2 AA Batteries
- 1 AA Battery Pack with switch
- 2 Alligator Clips
- 1 DC Motor

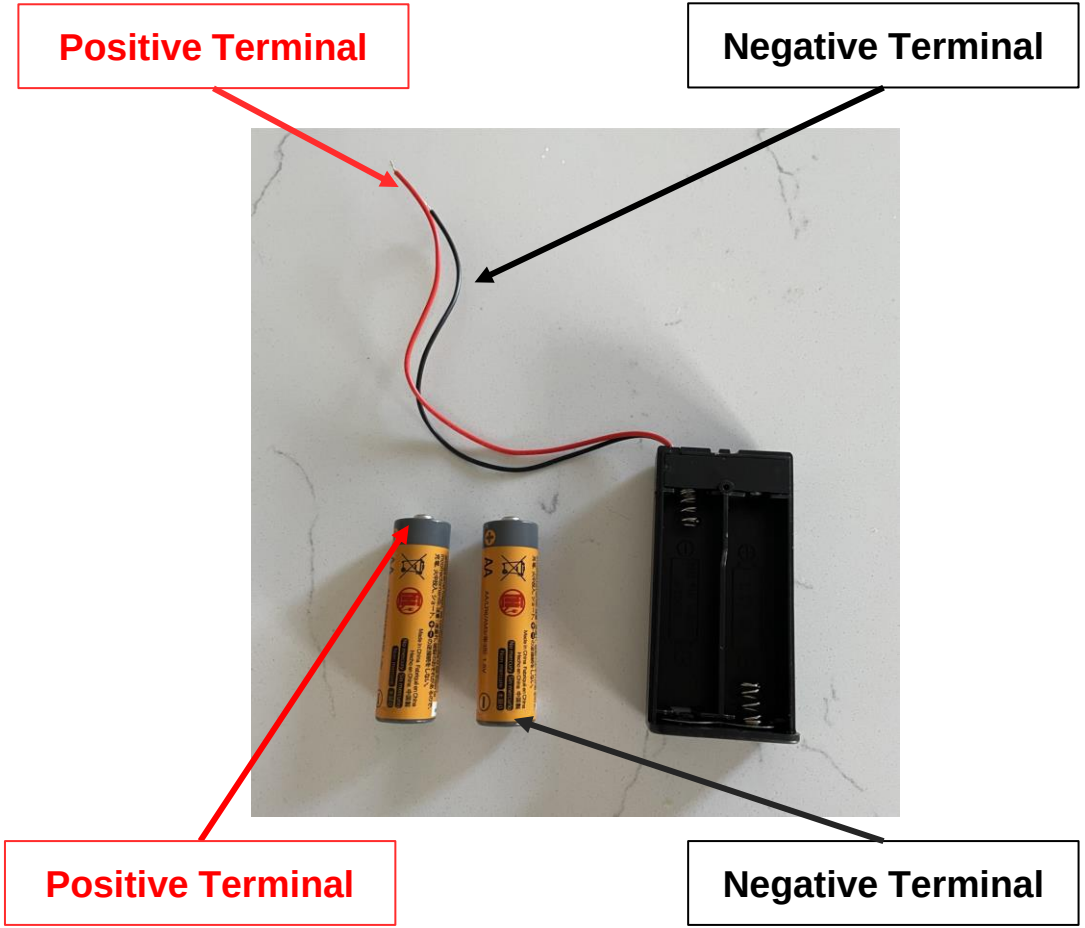


Step 1
Batteries:

The batteries will provide power to the electric motor.

AA batteries have a negative end (the flat side), and a positive end (the side with the bump).

Put two AA batteries in the battery pack.

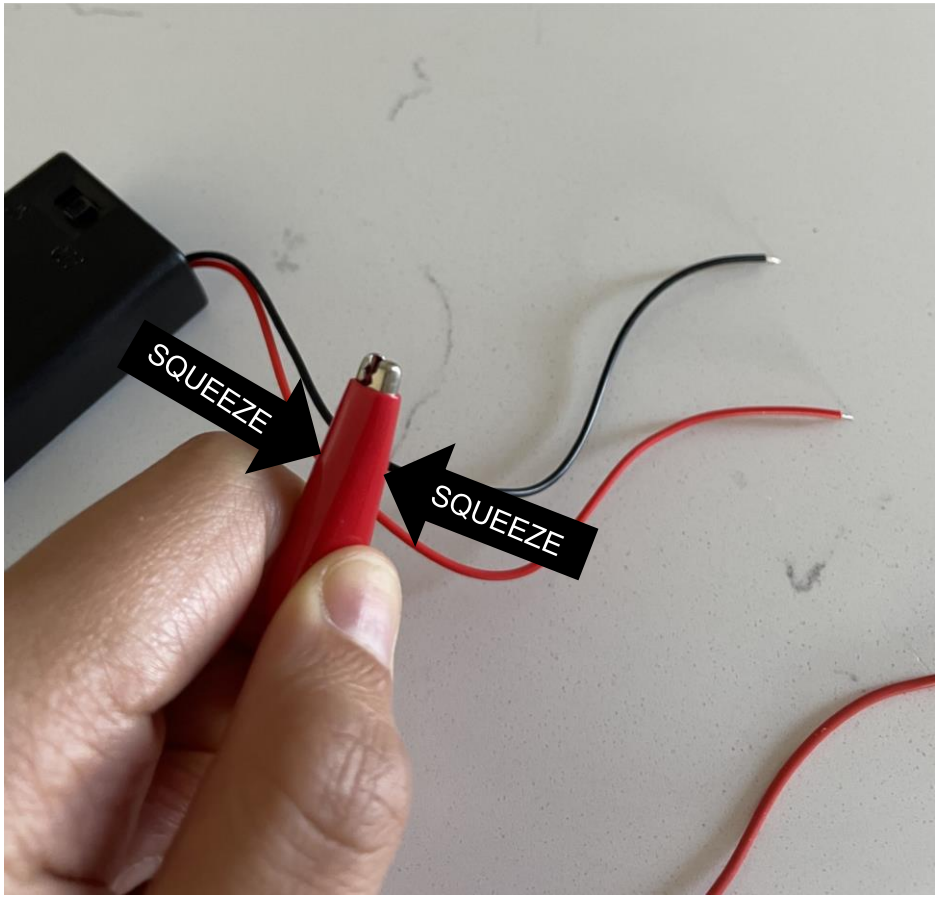


Step 2
Connectors:

For this circuit, we'll be using alligator clips. These allow us to connect terminals by clamping them together.

To open, squeeze the back end and let go to chomp!

A more permanent option is to solder the wires in the circuit.

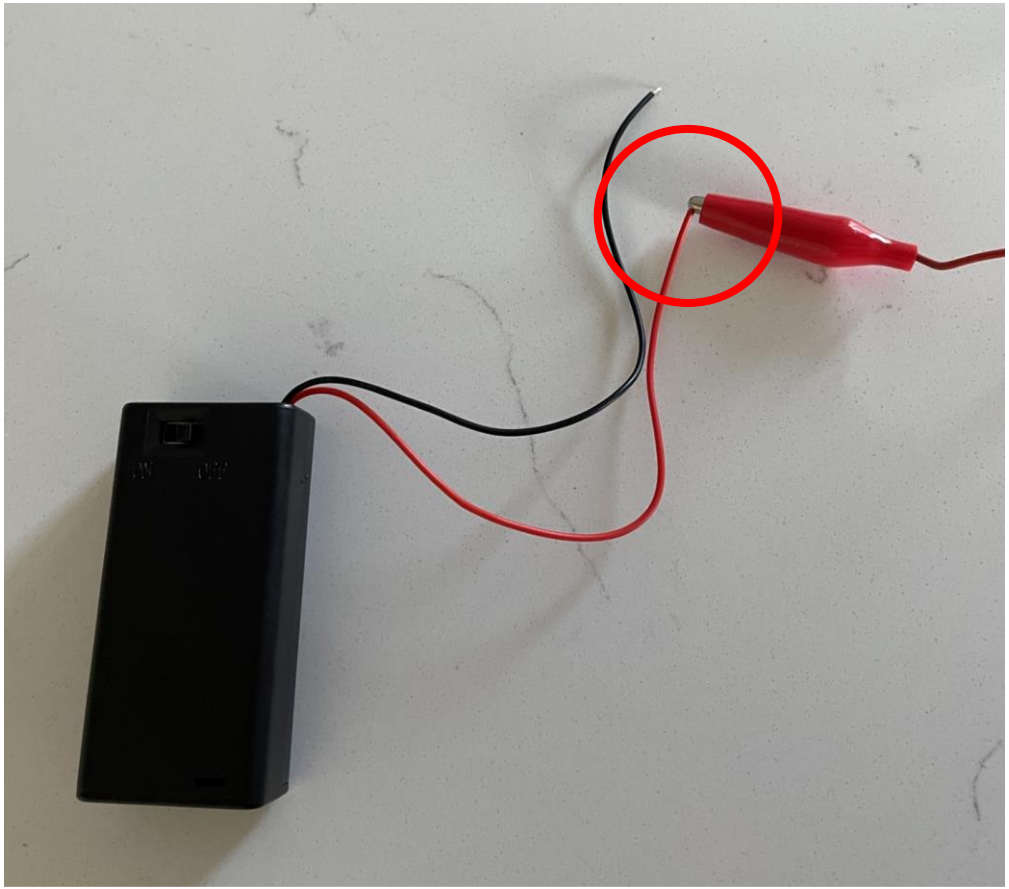


Step 3 Connections:

An electric current is the flow of charge (electrons) through a conductor, such as metal wires.

When you connect alligator clips to create a circuit, make sure the metal clip bites down on the metal leads.

If you connect to the rubber, there won't be any current!

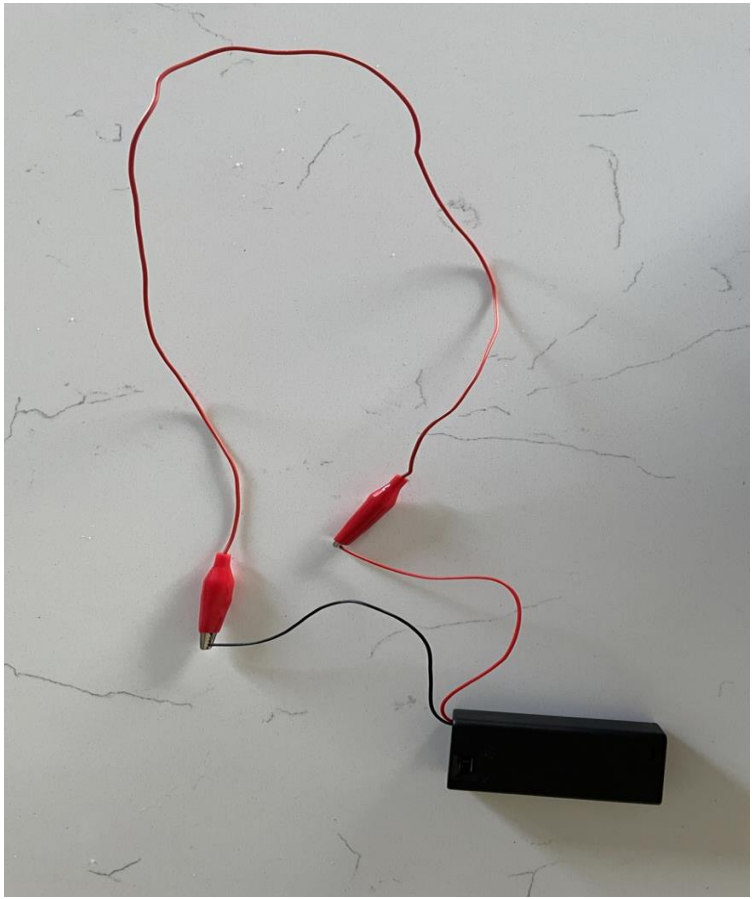


Step 4
Series Batteries:

We want to connect our batteries in **series**, meaning the **POSITIVE** end of the battery connects to the **NEGATIVE** end of the battery.

Series battery connections essentially creates one BIG battery.

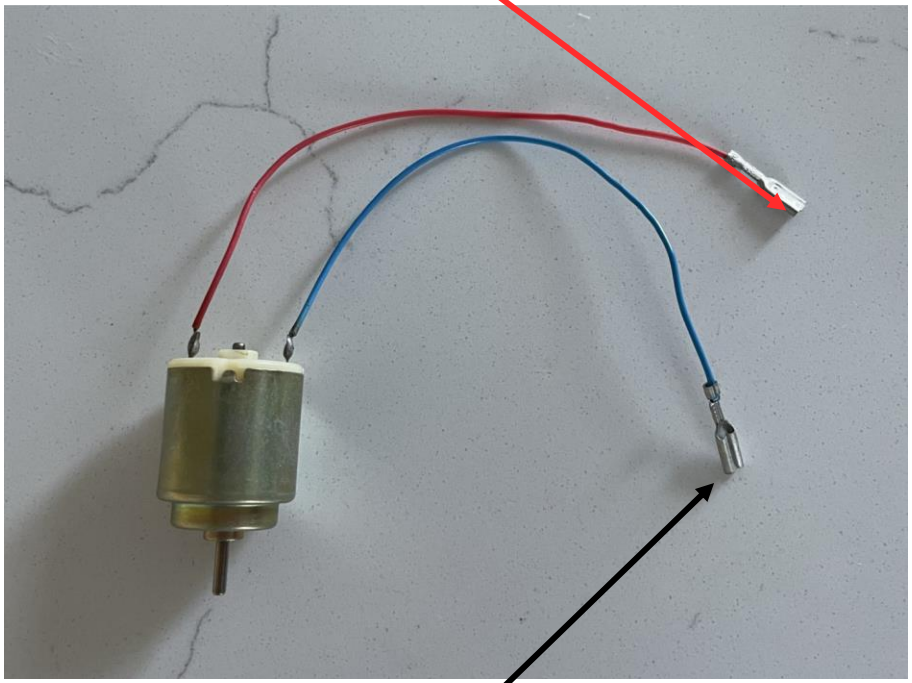
Instead of 1.5 Volts (that's the voltage of one AA battery), we will have:
1.5V + 1.5V = 3V total in our circuit!



Step 5
Electric Motor:

Next we'll add the motor to the circuit.

Like the battery pack, the **POSITIVE** end of the motor is the red wire and the **NEGATIVE** end of the motor is the blue wire.

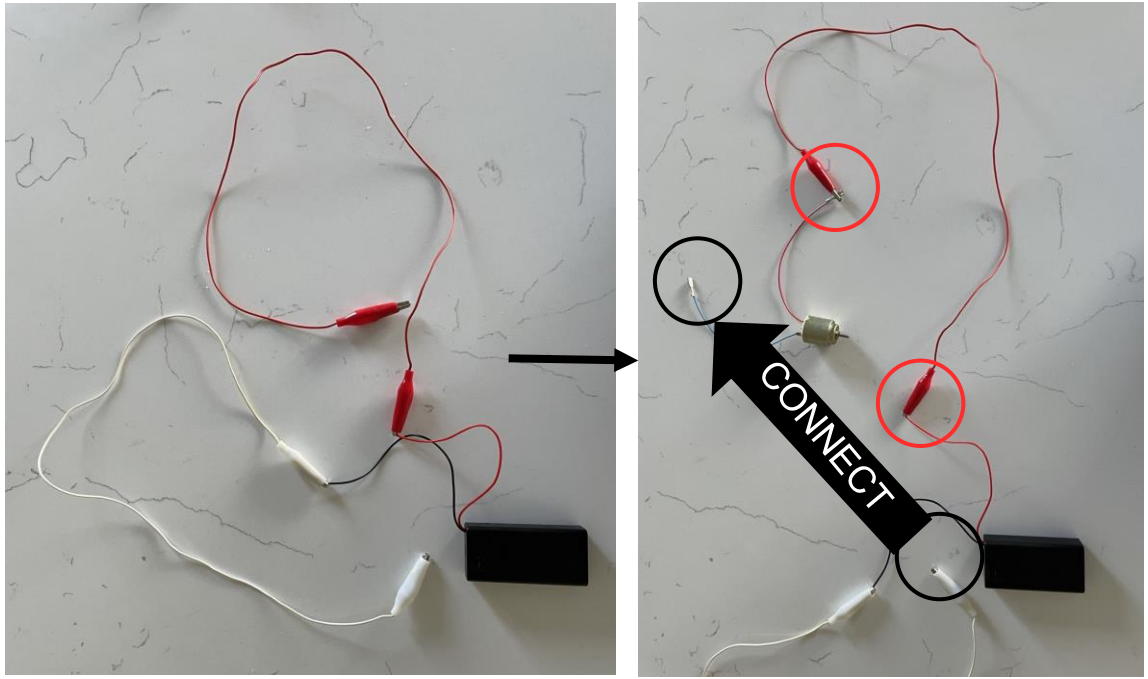


Step 6
Connect Motor:

Just like the batteries, we want the motor in *series*.

Use a set of alligator clips that connects to each end of the battery pack.

Then we'll connect the **POSITIVE** of the battery pack to the **POSITIVE** of the motor and the **NEGATIVE** of the battery pack to the **NEGATIVE** of the motor.

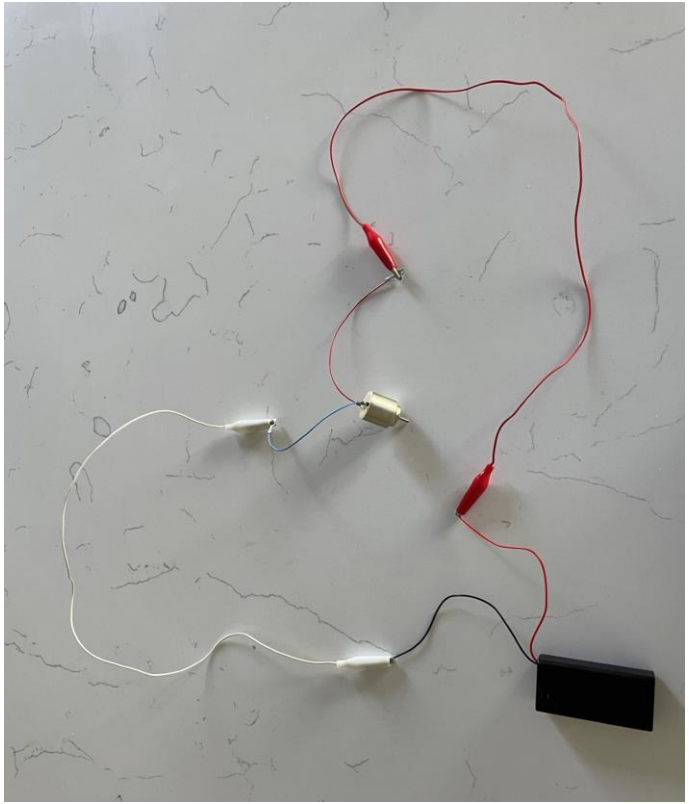


Step 7
Test the Circuit:

The circuit loop is complete. Turn the battery pack switch on and the electric motor should run!

Troubleshoot if the motor does NOT run:

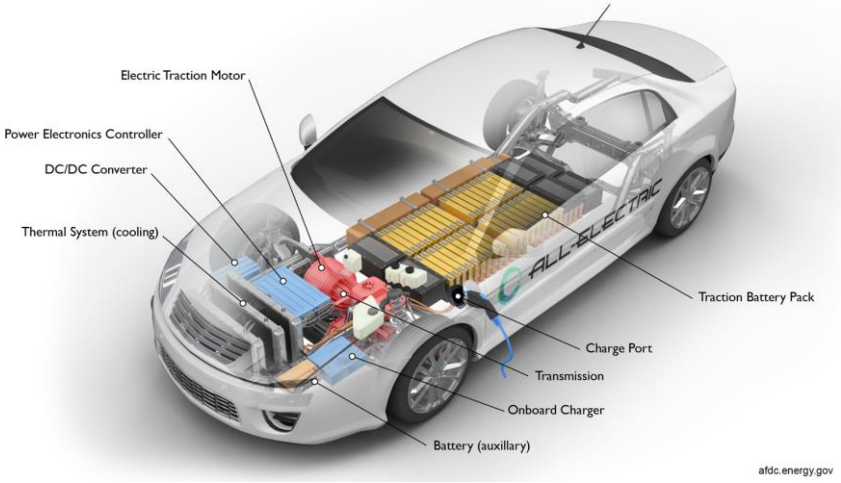
1) Trace the wires through the circuit, it should make one unbroken loop.
2) Give the motor spindle a gentle twist with the circuit on.



Circuits Review

1. Take a photo or short video of your completed electric motor circuit.
2. What components did you use?
3. How does your motor circuit work?
4. What is motor power source (type and number of batteries)?

All-Electric Vehicle



End of Workshop

Way to charge it!