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Smart Circuits Lab Worksheet

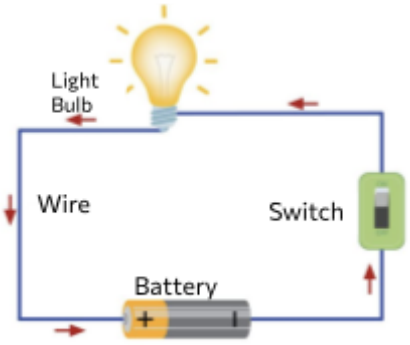
Here you will find the instructions to build and program practice circuits and a traffic light! Follow along with the video and complete all the instructions for this worksheet. Fill in the blanks as you go.

INTRODUCTION:

Embedded systems are a computer system made up of hardware (**circuits**) and software (**code**) to complete a specific task. For example, a cell phone is an embedded system, so is a digital watch, or your microwave!

What is a circuit?

A circuit is a **path for charge** to move. Moving charge transports **energy** across devices. A circuit is the way to control the movement of charge and energy from one point to another. A **battery** is the source of energy for a source. A **switch** is a device that can break and reconnect the loop of a current. We use switches to control when and where charge moves.



IMPORTANT: Energy only moves through conducting wires or wires connected to electrical components in a loop! The light will only turn on when the switch is on and there is connection between the positive and negative ends of the battery.

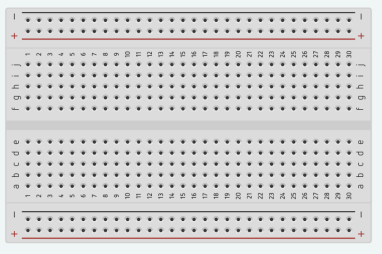
SET UP TINKERCAD:

We will be using www.tinkercad.com to learn about circuits. This is a free programming simulator that allows you to build and code your own embedded systems. Go to the website and create an account using your email.

Once you have logged in, go to your dashboard and click the "**Designs"** tab, then click the "**Circuits**" tab, and click the "**+Create"** to start making your circuit!

In Tinkercad, you can **select** and **drag** components into the build window and connect them with wires.

PART ONE: BREADBOARDS



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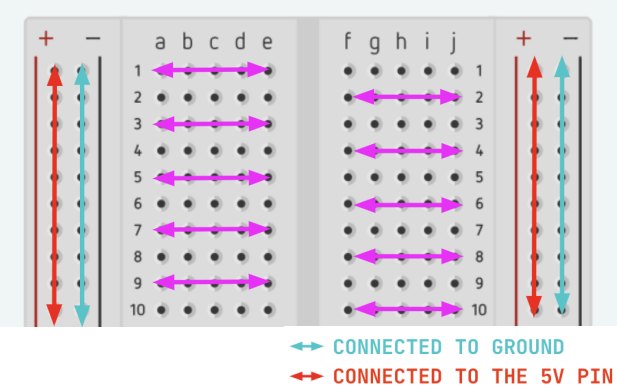
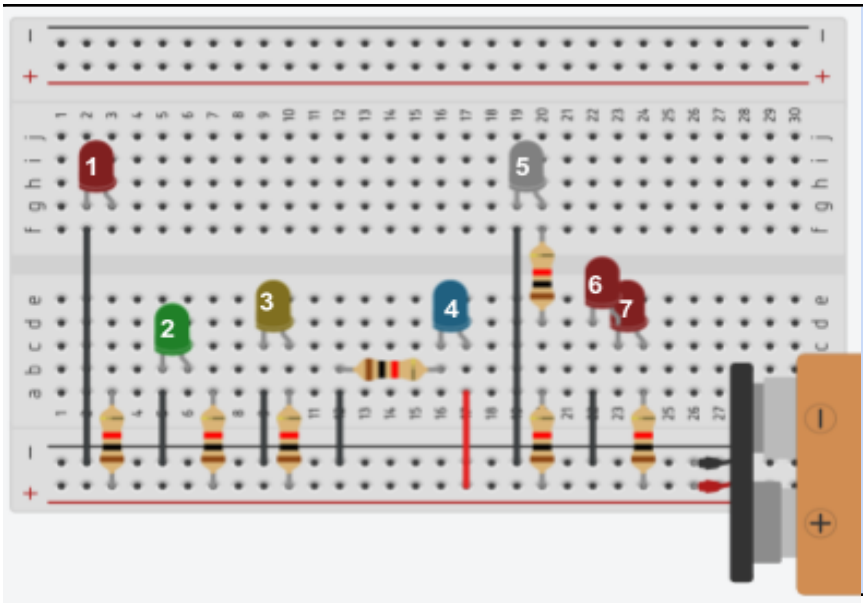
A **breadboard** is a plastic case that holds metal rails arranged in rows and columns that allow you to connect multiple circuit elements together quickly.

<u>Flow of Current in a Breadboard:</u>
Power Rails on breadboards direct electrical current vertically on the sections labeled + or -, and horizontally across numbered rows. You must use wires to connect one section to another, the electricity doesn't "hop" to other sections.



ACTIVITY 1:



<u>Answer Me!</u> Which LED(s) will light up if we start the simulation? Why?

Build in Tinkercad by drag and dropping breadboard, resistors, LEDs, and wires to test your answer!

PART TWO: OHM'S LAW

Ohm's Law is a rule that says $I = \frac{V}{R}$ where I is the current, V is the voltage, and R is the resistance in a circuit.

- **Current** is the rate of flow of charge, measured in Amps (A)
- **Voltage** is the force that electrons flowing through a circuit feel, measured in Volts (V)
- **Resistance** is the difficulty current has flowing in a circuit, measured in Ohms (Ω)

Therefore we can understand that as resistance <u>increases</u>, the amount of current <u>decreases</u> if voltage is <u>constant</u>.

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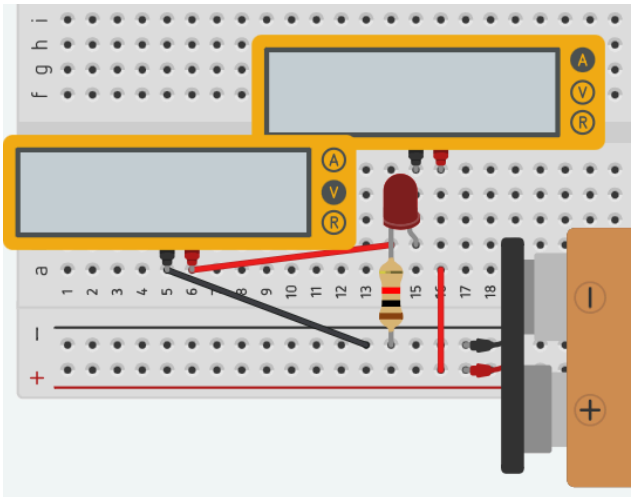
ACTIVITY 2:

1. Recreate the circuit shown using a battery, breadboard, multimeters, a resistor, an LED, and wires.
2. Place one multimeter in amperage mode (top right), and the other in voltage mode (left).
3. Try to follow the path of electricity from red (+) at the battery through all the devices to ground (-) at the battery.



Calculate the current (using Ohm's Law) and use tinkercad to verify the results. Vary the resistance of the resistors by clicking on them. Be sure the units are Ω not kΩ!!

Voltage (V)	Resistance (Ω)	Calculated Current (mA)	Tinkercad Current (mA)
	900		
	300		
	20		

Answer Me! What happens to the current as you decrease the resistance in the circuit?

A note on batteries...

When you complete this activity, you may notice that the voltage values don't remain constant - the voltage changes as you vary the resistance. Why would we get different values for voltage if the battery is the same?

Tinkercad is programmed to exactly mimic devices in real life where our devices are *non-ideal*: the device is designed to meet some criteria (e.g., "supply 9 Volts") but rarely does a device meet their constraints perfectly!

Don't worry about the different voltage values. This is normal and expected, and the results reflect how your circuit would behave in real labs!

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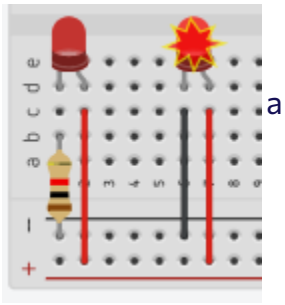
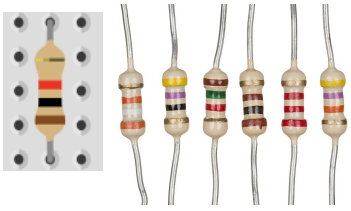
Short Circuits

If the resistance along a path is *too low* and we keep the voltage *constant*, then the current in our circuit will get *dangerously high*. This results in a short circuit. The LED on the right is an example of a short circuit in tinkercad. There is no resistance in the circuit on the right so the current becomes too large! The red star over the LED indicates too much current. **Short circuits can be very dangerous!**



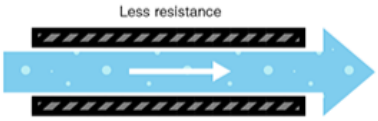
Answer Me! How can we avoid short circuits?

PART THREE: CIRCUIT COMPONENTS

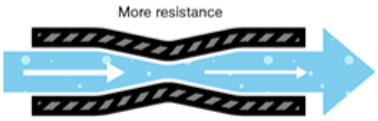


RESISTORS

Resistors are nearly the same as regular wires, except they add resistance to reduce current. They are crucial in avoiding short circuits, which may cause damage to your device.



Resistance can be thought of like tightening a water pipe. The flow, or current, would be decreased with more resistance. Higher resistance means less current flows through the circuit.

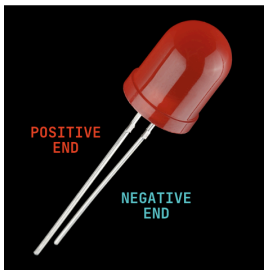


DIODES & LEDs

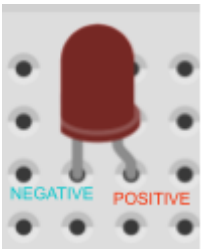
A **Light-Emitting Diode (LED)** is a device that emits light when a current runs through it. All diodes are **polar**: they only allow current to flow in **one direction**!

Note: LED's only glow when *enough* current flows through it in the right direction. The more resistance you add before connecting the LED, the dimmer your LED will be.

Real LED:



Tinkercad LED:



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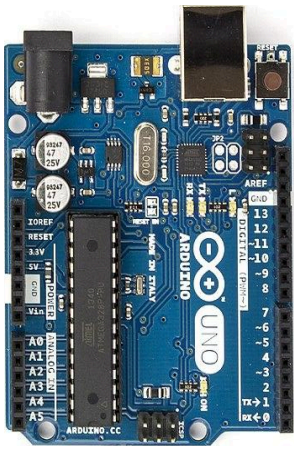
ARDUINO MICROCONTROLLER

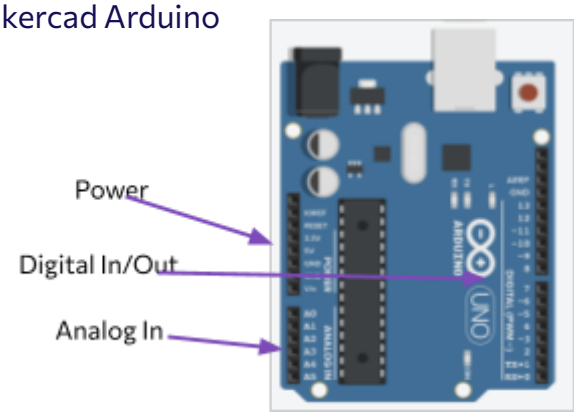
A microcontroller is a small computer with memory and programmable input and output pins. This Arduino has three types of pins:

- Power: used to supply energy like a battery, we will use the 5V and GND pins
- Analog in: takes in signals from a sensor, measures voltages between 0-5V
- Digital In and Out: a source of voltage that you can set to HIGH (5V) or LOW (0V) like a switch. We use code to open and close these switches.

Real Arduino



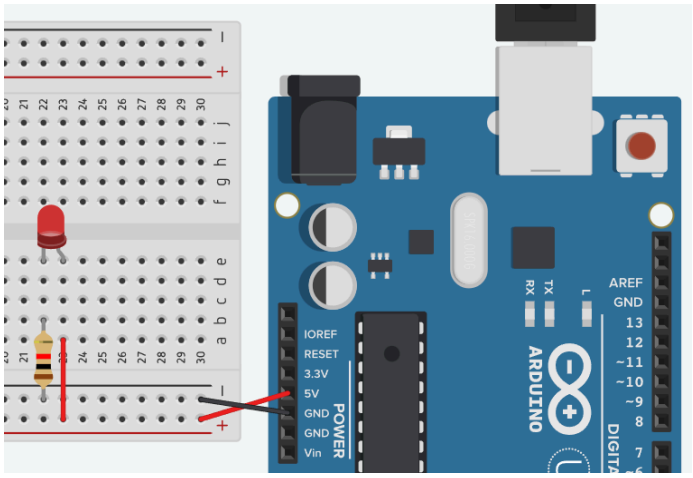
Tinkercad Arduino



ACTIVITY 3: DOES DIRECTION MATTER?

Let's experiment with the circuit components we've introduced!

1. Build the circuit shown. Instead of a battery, we're using our Arduino power pins (5V and GND) as our new power supply.
2. Run the simulation – the LED should light up.
3. Now, reverse the power leads of your circuit – switch the red and black wires so that 5V is connected to the (-) rail and GND is connected to (+).



4. Run the simulation again – the LED should fail!

We know that LEDs are sensitive to the direction of the current running through it – they only light up when current is flowing in the correct direction!

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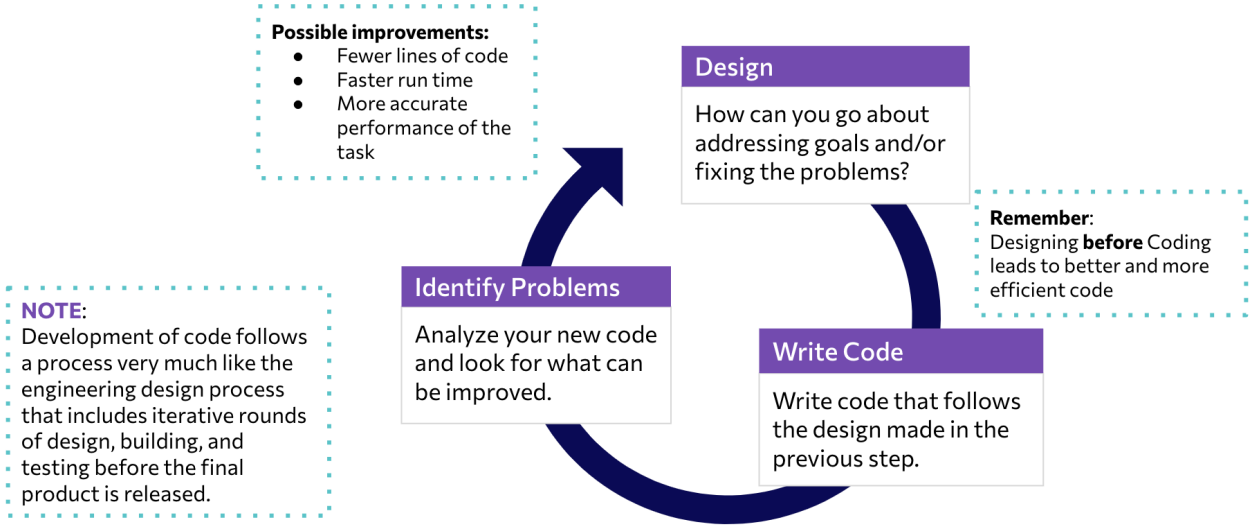
Answer Me! Knowing what we know about LEDs, what might have happened to the current when we reversed the power leads?

Using your theory, find a way to modify the circuit so that the LED lights up **without modifying the power supply.** (Hint: remember that you can rotate components).

PART FOUR: PROGRAMMING - BLINKING

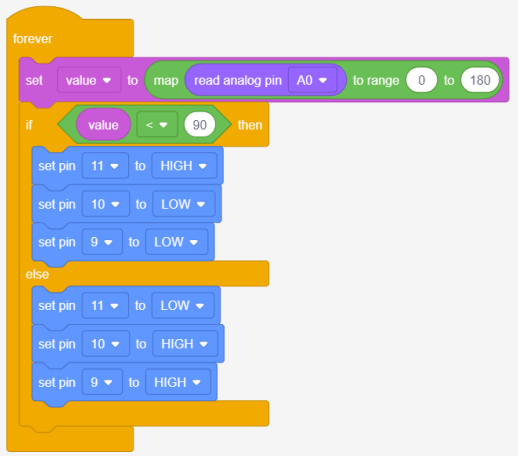
The digital pins on the Arduino are programmable switches labeled 0-13. They can be used to switch voltage on/off, or HIGH/LOW. This outputs a voltage of either 5V or 0V respectively. For this lab, we will use these pins to control our circuit with code.

The Coding Design Process:



Working with Block Code:

Block code is a simple way of programming your embedded system by chaining different instruction blocks together. It's a great introduction to coding that shows the logic behind programs without the nitty-gritty specifics of a text-based language!



The image on the right shows an example block-coded program for an embedded system. Open the "code" editor in Tinkercad to make your own block code programs – we'll make our first program in the next activity!

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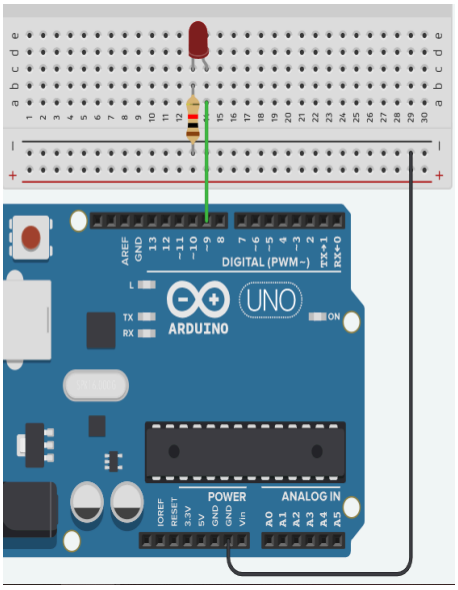
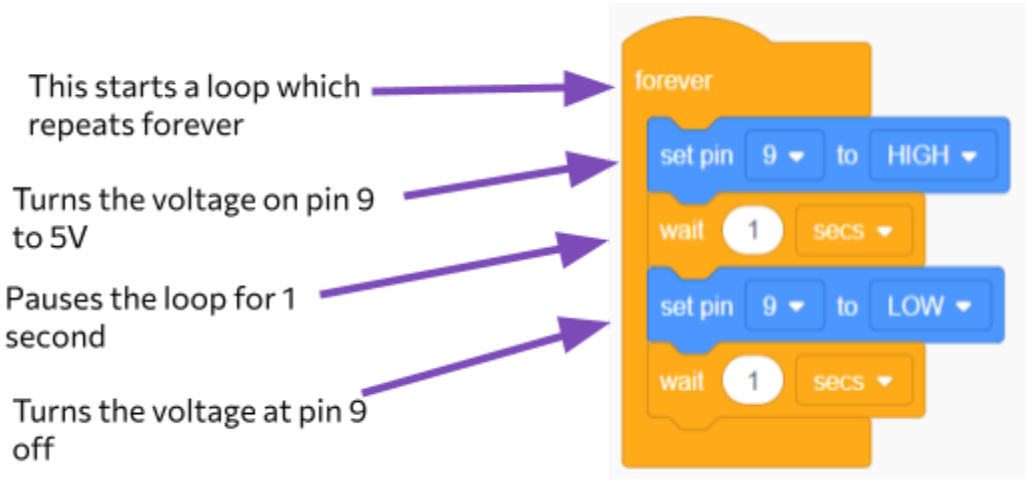
ACTIVITY 4: BLINKING CIRCUIT



1. Clear your breadboard and construct this circuit (you can use any pin 0-13 as long as your use the same number in your code).
2. Open the "Code" window and write a program that cycles the LED between being on and off for one second each. You can use the code below to program your circuit. Once you have your code in, run the simulation.
3. You should have an automatically blinking light! Try to manipulate the code to change the frequency of the blinking. Make your light blink 2 times per second!



PART FIVE: PROGRAMMING - FINAL CHALLENGE

ACTIVITY 5: TRAFFIC LIGHT

How can we make a traffic light with what you have learned?

1. Create a set of circuits on the board controlling a red, yellow, and green LED with 3 digital pins, each should end at the GND pin as above.
2. Write code that holds the green light for 3 seconds, then the yellow for 1 second, and finally the red for 3 seconds. Just like a real traffic light, turn on one light at a time with no delay between colors!

Hint: Look at the other programs provided for you for Part 4. Try to reuse parts of the code to create a new one for this problem.

Answer Me! Describe what steps should be taken at each point for this code (e.g., “first turn on..., next...”)

PART SIX: REFLECTION

Answer Me! What do you think went well when completing this activity? What is something you would do differently if you were to do this again?

STEP SEVEN: STUDENT EXIT SURVEY

Once you've finished the lab, please complete the student exit survey to share your feedback.