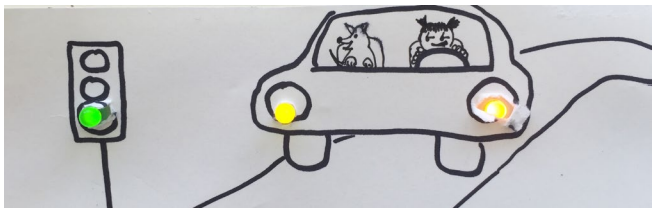
WEEK 1 DAY 1: LED PAPER CIRCUITS



INTRODUCTION

Makers are introduced to a fun and creative project that teaches basic electronics, art, and problem-solving.

ESSENTIAL QUESTIONS

- How does electricity make bulbs light up?
- How do artists, engineers, and makers solve problems when they're working?

LEARNING OUTCOMES

1. Learn basic electronics principles.
2. Engage in project-based learning through problem-solving to create an illuminated piece of art with LEDs.

VOCABULARY

LED: Light-emitting diode

Circuit: Loop through which electrical current can flow

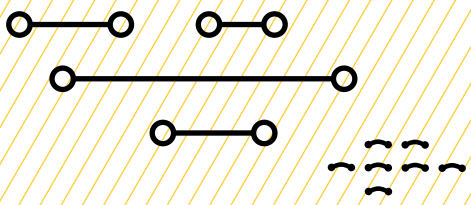
Polarity: Two poles that create an electric charge (e.g., north/south of a magnet or the Earth)

Conductive: Materials that allow the flow of electricity through (e.g., aluminum, copper, water)

Insulating: Materials that block the flow of electricity through (e.g., wood, plastic, tape)

Parallel circuit: Circuit that distributes an even amount of charge to each LED

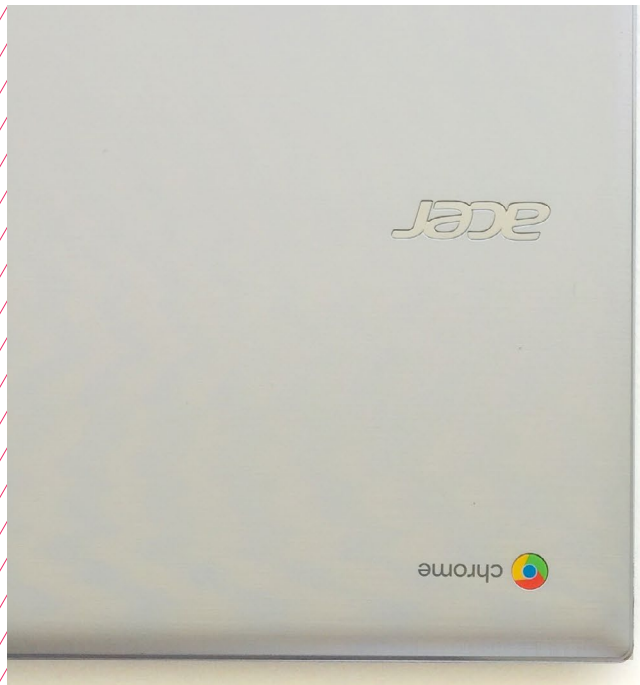
Troubleshooting: Using resources to solve issues as they arise

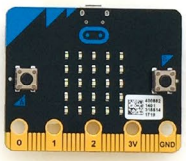


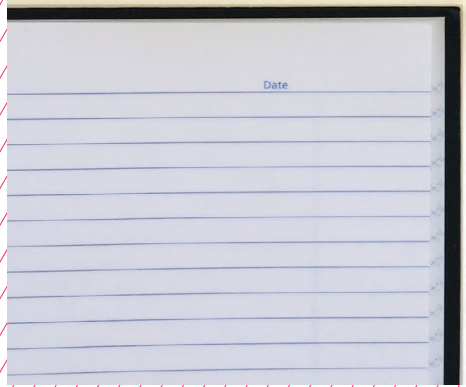
MATERIALS LIST

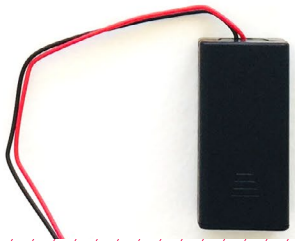
EACH PAIR OF MAKERS NEEDS:

- Circuit template
- 3V coin cell battery
- Small binder clip
- 10” strips of copper tape (2)
- LEDs (1–3) blue + white or red + green + yellow
- Notebook
- Scissors
- Tape (painters or masking)
- Aluminum foil
- Markers
- Colored pencils









TEACHER PREP WORK

1. Print the **circuit template** onto cardstock (1 copy for each maker, and a few extras).
2. Precut 10" strips of copper tape.
3. Create your own example piece for reference.
4. Ensure the internet connection is working and connect your laptop to a projector or screen.
5. Preload the slideshow.
6. Print the **Troubleshooting Tips** at the end of the lesson and post in the classroom.

FACILITATION TIPS

Makers will likely grapple with some aspect of the circuit. This first week, encourage them in developing a habit of hands-on troubleshooting when something doesn't work. Encourage makers to use the troubleshooting guide and seek help from each other as much as possible before asking for your help.

Circulate and monitor for both collaboration and frustration.

Collaboration: Let smaller issues work themselves out. Record specific positive examples that you can share with makers in the moment or at the end of the project. These examples provide models for all learners.

Frustration: When frustration levels aren't high, let makers figure it out or keep facilitation low-touch by asking a question and walking away. When frustration levels are high, intervene more directly to help makers find some success.

ADDITIONAL RESOURCES

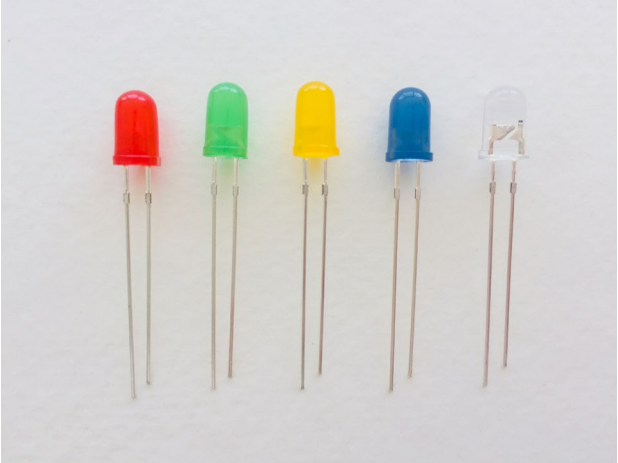
Exploratorium Paper Circuits

Maker Ed Paper Circuit Three Ways

Makerspaces.com Paper Circuits

Folding Copper Tape

LED PAPER CIRCUITS



STEP 1

3 MINUTES

Study the LEDs.

Group makers and give them several assorted **LEDs**.

Ask makers to study the LEDs and:

- Look closely at the LEDs.
- Draw what they see in their notebook.
- Label which leg is +/– on the LED.
- Label which side of the battery is +/–.

EXPLAIN

The longer leg is the + and the shorter is the – side. Both LEDs and batteries have polarity-opposite sides, and the +/– must touch the matching side of the battery to light up.

STEP 2

8 MINUTES

Explore electricity and the path of least resistance.

Give each maker a 3V battery.

Warning: Batteries can be fatal if swallowed.

EXPLAIN

Like LEDs, batteries have +/– polarity.

Point out that a 3V battery has a flat and a rounded side and that there's a + on the flat side.

Makers will now try lighting different LEDs with the battery. They'll notice that the red, yellow, and green LEDs light up together off one battery, and that blue and white also light up on a single battery, but that red and blue won't work together on the same battery.

Makers will:

- Write in their notebooks which colors light up together and which do not.

3V	red, yellow, green
3V	blue, white

EXPLAIN

Various LEDs take different amounts of voltage to light up. LEDs that require less voltage will always light up first, taking the "path of least resistance." Red LEDs require about 1.8V, while blue LEDs require about 3V. That's why the red and blue won't light up together. Keep this in mind when designing LED art.

STEP 3 (3 MINUTES)

Explore conductive and insulating materials.

As makers continue to experiment with the LEDs and batteries, explain that the metal of the battery and the legs of the LED are **conductive** materials, which means they allow electricity to pass through. And things like paper, plastic, and wood are **insulating** materials that don't allow electricity to pass through.

Makers will:

- Write down which materials are conductive and insulating in their notebook.

Conductive: Allows electricity to flow
(wire, aluminum, copper tape, paper clips)
Insulating: Blocks the flow of electricity
(masking tape, paper, plastic, wood)

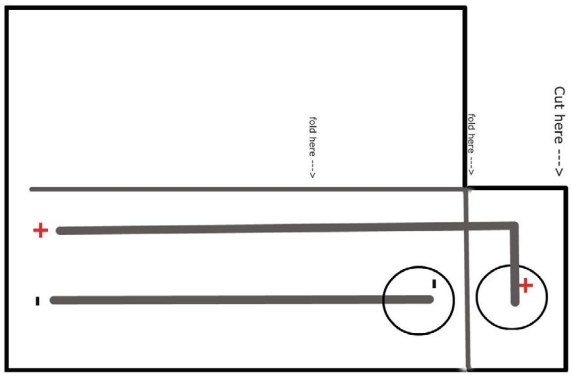
EXPLAIN

LEDs can be connected to conductive materials, like wire and copper tape, to allow electricity to flow. Materials like plastic, rubber, paper, and masking tape are insulating, which means they can be used to prevent electricity from going through. Then show makers your example project.

STEP 4 (15 MINUTES)

Create a parallel circuit with LEDs.

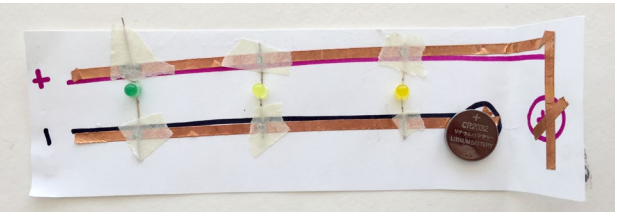
Makers use scissors, copper tape, battery and LEDs with the provided **parallel circuit** template.



Makers will:

- Cut the template out along the solid line.
- Carefully peel and stick copper tape along the tracks marked (+/–), making sure that the two tracks don't touch each other.

- Place the 3V coin cell in the fold with one side touching either (+/–) track, and place the binder clip to hold it in place.
- Mark the shorter leg of the LEDs with black permanent marker to keep track of the +/–.
- Carefully bend the LED legs and touch the matching (+/–) leg to the matching side of copper tape tracks. The LED should light up.



Note: To make a 90° angle with the copper tape, fold the tape into a 90° angle in the opposite direction, and then fold the tape back onto itself so it's going in the direction shown on the template, with the sticky side facing the paper. Be careful to not tear the tape while folding it or sticking it down on the paper. This video illustrates the technique.

STEP 5 25 MINUTES

Combine art and light.

Next, makers brainstorm the design/drawing they want to have appear on the front, essentially where they want the lights to shine through.

Makers will:

- Draw a few design ideas in their notebook.
- Choose the one they want to create, and draw it on the front side of the template.
- Choose the LEDs they want to use.
- Carefully bend the LEDs horizontally in position, bridging the copper strips like train tracks (without crossing the legs of each LED).
- Use aluminum foil and tape to secure the legs in position.

STEP 6 5 MINUTES

Clean up.

Makers will:

- Put any materials they want to keep using in their partner bin.
- Return tools and materials that can be used again to the right place.
- Clear tables of garbage and recycling.

WEEK 1 DAY 2: LED GUMMY BEAR CITY

INTRODUCTION

In this lesson, makers continue using LEDs, batteries, and copper tape to design 3D gummy bear cities.

ESSENTIAL QUESTIONS

- How can I design an electrical circuit?
- How do urban planners prototype public spaces they're designing?

LEARNING OUTCOMES

1. Gain further experience with electronics principles (battery, polarity, conductive, insulating, parallel circuit, LEDs, etc.).
2. Engage in project-based learning through problem-solving to create an illuminated piece of art with LEDs.

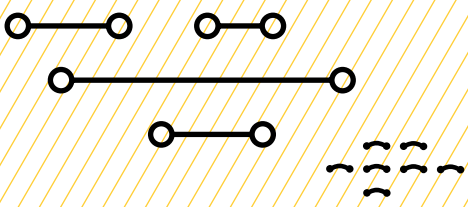
VOCABULARY

Urban planner: Person whose job is to develop plans and designs for the use of space within cities, towns, developments, etc.

Prototype: Early model of a project or product, built to test a concept or process

Engineering: Applying science and math to invent, design, and build things to solve problems

Troubleshooting: Using resources to solve issues as they arise



MATERIALS LIST

EACH PAIR OF MAKERS NEEDS:

- Circuit template, printed on cardstock
- Paper, various colors
- 3V coin cell battery
- Small binder clip
- Several 15” strips of copper tape
- LEDs, assortment of colors (RGBYW)
- Notebook
- Scissors
- Tape (painters or masking)
- Aluminum foil
- Markers
- Colored pencils
- Glue stick
- Gummy bears (at end of activity)

TEACHER PREP WORK

1. Ensure the internet connection is working and set up a projector.
2. Preload the slideshow.
3. Print copies of the **circuit template** onto white cardstock.
4. Cut copper tape into 15" strips.
5. Prepare your own example project (helpful as a reference).
6. Print the **Troubleshooting Tips** at the end of the lesson and post in the classroom.

FACILITATION TIPS

Makers will likely ask for the gummy bears immediately. You can explain that *"the gummy bears won't arrive until the city is closer to ready."*

You can encourage them to improve their craftsmanship by engaging in some role playing, *"Make sure to have a safety inspection crew check your structures before the gummy bears come in, just like in a real city."*

Makers will likely grapple with some aspect of the circuit. This first week, encourage them in developing a habit of hands-on troubleshooting when something doesn't work. Encourage makers to use the troubleshooting guide and seek peer-to-peer help as much as possible before asking for your help.

Circulate and monitor for both collaboration and frustration.

Collaboration: Let smaller issues work themselves out. Record specific positive examples that you can share with makers in the moment or at the end of the project. These examples provide models for all learners.

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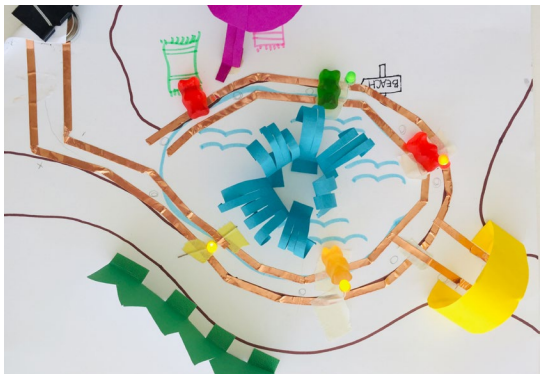
LED GUMMY BEAR CITY



STEP 1 5 MINUTES

Introduce gummy bear city.

EXPLAIN

As **urban planners** for gummy bear city, the makers' task is to plan and design **prototypes** of public spaces using paper, LEDs, and copper tape. Working in small groups, makers will design and build a layout that includes LED circuits. When they finish, everyone's creations will come together to create a whole city.

Ask makers:

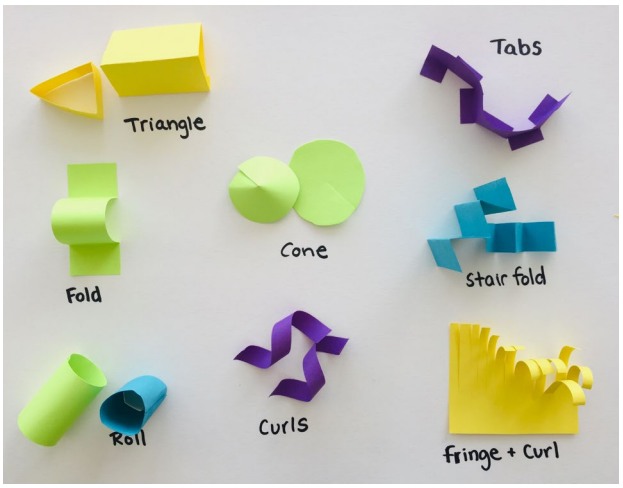
- Imagine it's the year 2050 (to encourage imaginative and futuristic spaces). What kinds of shared spaces and places do you think should be a part of gummy bear city?

Next, makers will:

- Brainstorm in their notebook ideas for spaces they want to create for the city (library, pool, school, gym, etc.).
- Draw a sketch of their plan and label the location and color of the lights they want to add.

STEP 2 5 MINUTES

Introduce paper engineering.



To add interest to their project, makers use paper folding and building techniques to make the spaces 3D. Show a few examples of paper **engineering** techniques that can help bring their gummy bear city to life. Makers can create using paper, glue sticks, and tape. (Optional: You can provide other small

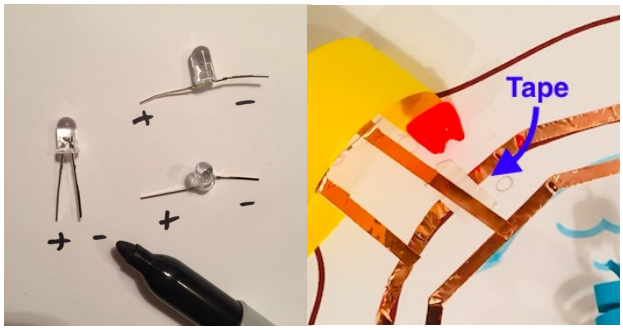
items, such as Q-tips and toothpicks, for them to build with.)

STEP 3 35 MINUTES

Combine circuits with paper engineering.

Makers use the rest of the time to work on their paper circuits combined with paper engineering. They may want to use different colored LEDs together. If so, they can add a second battery holder on the same page.

Ask makers to mark +/– of the LEDs and the copper tracks, using a permanent marker. They may find it challenging to keep track of the copper tape as they design, and this will help.



If lines of copper tape need to overlap, makers should insulate those sections by covering them with masking tape, creating a bridge so the copper lines don't touch. Two lines of copper tape touching (crossing of +/–) could cause a short circuit.

Makers will:

- Keep track of the polarity (+/–) of tracks.
- Use masking tape to insulate areas if copper tape must cross.
- Encourage makers to troubleshoot together.
- Persist through problems as they arise.

As they get closer to finishing, you can give each group gummy bears to populate their cityscapes!

STEP 4 10 MINUTES

Gummy bear city gallery walk and reflection.

Makers write in their notebooks, answering:

- What are you most proud of in your project?
- How did your group **troubleshoot** or overcome challenges?

Makers now put all the parts of the city together as a class and spend time sharing with the whole class what they created. If there's extra time, let makers play and interact with the gummy bear city! Make sure to leave time for cleaning up.

STEP 5

Clean up.

Makers will:

- Put any materials they want to keep using in their partner bin.
- Return tools and materials that can be used again to the right place.
- Clear tables of garbage and recycling.

TROUBLESHOOTING TIPS

LEDs aren't lighting up.	**Polarity +/- or short circuit** • LEDs could be reversed. Flip the orientation of the LED legs. • Make sure the legs of the LED aren't crossed.
LEDs aren't lighting up.	**Battery** • Try flipping the battery over. • Try replacing the battery.
LEDs are flashing but not staying on.	**Loose connection** • Try taping down more securely. • Add a bit of aluminum foil under the tape, on top of the LED leg, to help bridge the connection to the copper. • Copper tape might have a tear. Try to find the rip and bridge it with a little aluminum foil and tape.
LEDs are flashing, and some light up while others turn off.	**Color and voltage** • Try switching the colors of your LEDs. • You can use blue and white LEDs on the same circuit and red, yellow, and green on the same circuit, but not blue and red or yellow and white.
Paper isn't holding its shape.	• Add more glue, and hold in place for at least 20 second while it's drying. • Create a support piece by gluing an overlapping paper tab, or make an L-shaped bracket with paper. • Try using different thicknesses of paper.

TROUBLESHOOTING TIPS

Print and use the empty rows to fill in with other problems and solutions that can be shared.