Paper Circuits: Bringing Art, Engineering, and Electricity to Life

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Goals and Objectives

Project Goal

The goal of this Paper Circuits unit is to provide students with an accessible, hands-on introduction to electrical circuits and engineering design. Using simple materials such as copper tape, LEDs, paper, and coin-cell batteries, students transform traditional paper projects into functioning electrical designs.

Paper circuits provide students with an opportunity to learn about electricity through experimentation rather than only through diagrams or notes. Students are able to immediately see whether their designs work, identify problems when they do not, and modify their designs until they are successful.

The project also encourages students to see STEM as a creative process. Circuits can be incorporated into greeting cards, artwork, models, posters, and other student-created products.

Student Objectives

By the completion of the project, students will be able to:

- Identify the major components of a simple electrical circuit.
- Distinguish between an open circuit and a closed circuit.
- Identify the positive and negative sides of an LED and coin-cell battery.
- Construct a functional circuit using copper tape, an LED, and a coin-cell battery.
- Create and interpret a basic circuit diagram.
- Compare series and parallel circuit arrangements.
- Apply the engineering design process to plan, construct, test, and improve a circuit.
- Troubleshoot common problems within a paper circuit.
- Incorporate an electrical circuit into a creative final product.
- Explain how changes to a circuit affect its performance.

Project Overview

Electricity is often introduced to students using circuit diagrams, vocabulary, or preassembled circuit kits. While these tools can be valuable, students may have difficulty connecting a diagram on a page to the movement of electrical energy through an actual circuit.

Paper circuits provide a simple and inexpensive bridge between these ideas.

A paper circuit is an electrical circuit constructed on a paper surface. Conductive copper tape replaces traditional wires, while small LEDs provide a visible output. A coin-cell battery provides the electrical energy necessary to illuminate the LED.

The simplicity of the materials makes paper circuits particularly useful as an introductory engineering activity. Students do not need previous experience with electronics, soldering, breadboards, or programming.

The project is designed as a progression.

Students first construct a basic circuit to understand how the components work. They then apply this knowledge to a creative light-up card. Finally, students investigate how multiple LEDs can be incorporated into a design and compare series and parallel circuits.

Throughout the activities, students are encouraged to predict, build, test, troubleshoot, and redesign. A circuit that does not illuminate is not immediately considered a failed project. Instead, it becomes an opportunity for students to determine where the circuit is incomplete and make modifications.

Suggested Grade Levels

Grades 4–12

The complexity of the project can easily be adjusted for different age groups. Younger students may focus primarily on complete circuits, polarity, and creating a light-up design. Older students can incorporate circuit diagrams, series and parallel circuits, voltage, resistance, switches, and engineering constraints.

Suggested Time

The complete sequence can be taught over approximately three class periods.

Lesson 1: Introduction to Paper Circuits – 30–45 minutes
Lesson 2: Light-Up Circuit Card – 45–90 minutes
Lesson 3: Series and Parallel Circuit Challenge – 45–90 minutes

Teachers may also select only one lesson for a shorter activity.

Florida Standards

Paper circuits can support standards related to physical science, engineering design, scientific investigation, and the application of scientific knowledge.

Teachers should select standards appropriate to the grade level and course in which the activity is implemented.

SC.5.P.11.1 – Investigate and illustrate the fact that the flow of electricity requires a closed circuit (a complete loop).

SC.5.P.10.4 – Investigate and explain that electrical energy can be transformed into heat, light, sound, and motion.

SC.4.P.10.2 – Investigate and describe how electrical energy moves through a complete circuit and can be transformed into other forms of energy.

SC.3.P.11.1 – Investigate and identify materials that conduct electricity and materials that do not conduct electricity.

SC.912.N.1.1 – Define a problem and conduct scientific investigations by collecting data, using evidence, and communicating results.

***Because paper circuits can be used across multiple grade levels and courses, teachers can also connect the activity to standards involving:

- Electrical energy
- Energy transfer
- Scientific investigation
- Models
- Engineering design
- Problem solving
- Testing and redesigning solutions
- Applying scientific concepts to real-world problems

Teacher Background Information

What Is a Circuit?

An electrical circuit is a complete pathway through which electric current can flow.

For the paper circuit activities in this packet, the circuit consists of three primary components:

Power source: Coin-cell battery
Conductive pathway: Copper tape
Output: Light-emitting diode, or LED

For the LED to illuminate, these components must form a complete pathway.

Open and Closed Circuits

A **closed circuit** contains a complete pathway through which electrical current can travel. When students create a complete pathway from the battery, through the LED, and back to the battery, the LED can illuminate.

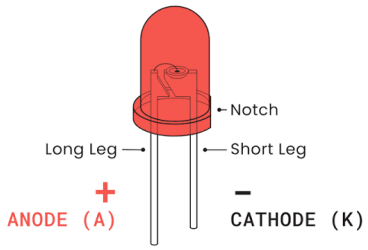
An **open circuit** contains a break somewhere in the pathway. The LED will not illuminate because the pathway is incomplete.

This distinction provides a useful troubleshooting question:

"Where is the circuit open?"

Rather than immediately fixing a student's circuit, teachers can encourage the student to trace the complete pathway with a finger.

LED Polarity



LED stands for **light-emitting diode**.

Unlike a traditional small light bulb, an LED has polarity. This means its orientation in the circuit matters.

A typical LED has two leads:

- The longer lead is the positive lead, or anode.
- The shorter lead is the negative lead, or cathode.

Students must connect the positive LED lead toward the positive side of the battery and the negative LED lead toward the negative side.

If the LED is installed backward, it will not illuminate.

A useful troubleshooting technique is simply to reverse the battery. If the LED illuminates after the battery is reversed, polarity was the problem.

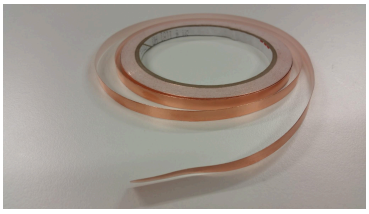
Coin-Cell Batteries 

Coin-cell batteries are small batteries commonly used in paper circuits.

The positive side is typically the large flat side marked with a + symbol. The opposite side is negative.

Students should be taught to identify these sides before beginning construction.

Copper Tape



Copper tape acts as the conductive pathway in a paper circuit.

Students create two copper pathways:

Positive pathway: Battery positive → LED positive

Negative pathway: LED negative → Battery negative

The two pathways should not touch each other directly. If they do, students can create a short circuit.

Materials and Preparation

Materials Per Student or Pair

- 2 coin-cell battery
- 1–3 LEDs
- Conductive copper tape
- Cardstock or heavy paper
- Pencil
- Colored pencils, crayons, or markers
- Scissors
- Clear tape
- Circuit planning sheet

Optional Materials

- Additional LEDs
- Small motors
- Buzzers
- Conductive fabric or other conductive materials
- Decorative craft materials
- Stickers
- Construction paper
- Rulers

Teacher Preparation

Before beginning the lesson:

1. Test several batteries and LEDs.
2. Create one working paper circuit as a demonstration.
3. Create one circuit with an intentional error for troubleshooting.
4. Cut copper tape into manageable lengths if desired.
5. Organize LEDs and batteries into student sets.
6. Print circuit planning sheets.
7. Prepare an example light-up card.

Teacher Tip

Avoid giving students a finished circuit template immediately.

Allowing students to first determine how the battery, copper tape, and LED need to connect encourages more reasoning and troubleshooting.

Lesson 1: Introduction to Circuits

Lesson Overview:Before students design their own paper circuit card, they need an understanding of how electrical circuits work. In this lesson, students explore circuits by constructing three different paper circuits using the provided worksheets:

1. **Simple Circuit**
2. **Series Circuit**
3. **Parallel Circuit**

Students begin with a simple circuit to investigate open and closed circuits and the polarity of an LED. They then build series and parallel circuits and compare how the arrangement of components changes the circuit.

The goal is for students to learn circuit concepts through building, testing, and troubleshooting. The three worksheets provide students with the copper tape pathways and component locations so that they can focus on understanding how the circuits function before designing a circuit independently in Lesson 2.

Learning Objectives: By the end of the lesson, students will be able to:

- Identify the basic components of an electrical circuit.
- Explain the difference between an open and closed circuit.
- Identify the positive and negative sides of an LED and coin-cell battery.
- Construct a simple closed circuit.
- Explain the difference between series and parallel circuits.
- Construct series and parallel paper circuits.
- Compare the behavior of series and parallel circuits.
- Troubleshoot a paper circuit that does not initially work.
- Apply observations from the investigation when designing an original paper circuit.

Materials:

Per Student or Pair

- 1 **Simple Circuit Worksheet**
- 1 **Series Circuit Worksheet**
- 1 **Parallel Circuit Worksheet**
- Conductive copper tape
- 2–3 LEDs
- Coin-cell battery
- Clear tape
- Pencil

Part 1: Introducing Electrical Circuits

Begin by showing students an LED and coin-cell battery.

Ask: **What do we need to do to make this LED light?**

Allow students to make predictions.

Give each student or pair an LED and battery and allow them to experiment with making the LED illuminate before introducing the worksheet.

Once students successfully illuminate the LED, ask them to turn the battery or LED around.

Discuss what happens.

Introduce the three major components students will use:

Power Source: Coin-cell battery
Conductive Pathway: Copper tape
Output: LED

Explain that electricity must have a complete pathway through these components for the LED to illuminate.

LED Polarity

Have students examine the two leads of their LED.

Explain that LEDs have polarity, meaning that the direction they are placed in the circuit matters.

The longer LED lead is typically the **positive lead**, and the shorter lead is the **negative lead**.

Students will see **+ and − markings on their circuit worksheets** to help them correctly position their LEDs and batteries.

Part 2: Simple Circuit Worksheet

Distribute the **Simple Circuit Worksheet**.

Explain that the brown pathway on the worksheet represents where students will place their conductive copper tape.

The worksheet also identifies the location and orientation of the LED and battery.

Construct the Circuit

Have students:

1. Place copper tape directly over the circuit pathway shown on the worksheet.
2. Leave the indicated space for the LED.
3. Position the LED so that the positive and negative leads correspond with the markings on the worksheet.
4. Secure the LED leads against the copper tape.
5. Position the coin-cell battery in the indicated location.
6. Press the circuit closed.
7. Observe the LED.

Once students successfully illuminate the LED,

Ask:**Is this circuit open or closed right now?**

Students should identify that the circuit is **closed** because there is a complete pathway.

Next, have students intentionally break the pathway by lifting the battery or separating one connection.

Ask:**What happened to the LED?**

Introduce the term **open circuit**.

Open vs. Closed Circuit

Closed Circuit:
A complete pathway exists, allowing electrical current to flow through the circuit.

Open Circuit:
There is a gap or break in the pathway, preventing current from flowing through the complete circuit.

Have students alternate between opening and closing their simple circuit.

Ask:

- What happens when the circuit is closed?
- What happens when the circuit is open?
- What part of your circuit acts as a switch?
- What would happen if there were a break in the copper tape?

Explain that this concept will become especially important when students begin troubleshooting their own card designs.

Part 3: Series Circuit Worksheet

Once students understand the simple circuit, distribute the **Series Circuit Worksheet**.

Tell students:

> **Our first circuit contained one LED. Now we are going to investigate what happens when we add another LED to the same pathway.**

Before students build, have them examine the worksheet.

Ask:**How is this circuit different from the simple circuit?**

Students should notice that there are now two LEDs positioned along the same pathway.

Introduce the term **series circuit**.

Series Circuit

In a series circuit, components are connected along a single pathway.

Have students predict:

- Will both LEDs illuminate?
- Do you think the LEDs will be equally bright?
- What do you think will happen if one LED is removed or disconnected?

Students should record or discuss their predictions before testing.

Construct the Series Circuit

Using the worksheet as a guide, students:

1. Place copper tape over the pathway.
2. Position both LEDs according to the polarity markings.
3. Secure the LED leads against the copper tape.
4. Position the battery.
5. Close the circuit.
6. Observe what happens.

Have students record their observations.

Next, have students disconnect one LED.

Ask:**What happened to the other LED? Why?**

Guide students back to the idea of a **complete pathway**.

Because the components are arranged along one pathway, interrupting that pathway creates an open circuit.

Part 4: Parallel Circuit Worksheet

Distribute the **Parallel Circuit Worksheet**.

Before adding any materials, ask students to compare the printed pathway with the Series Circuit Worksheet.

Ask:**What do you notice is different?**

Students should recognize that the circuit now contains multiple pathways or branches.

Introduce the term **parallel circuit**.

Parallel Circuit

In a parallel circuit, components are placed on separate branches of the circuit, creating more than one pathway.

Before building, have students predict:

- Will both LEDs illuminate?
- How might this compare with the series circuit?
- What will happen if one LED is removed?
- Will the other LED still have a complete pathway?

Construct the Parallel Circuit

Students:

1. Place copper tape over the pathways shown on the worksheet.
2. Position each LED according to the polarity markings.
3. Secure the LED leads against the copper tape.
4. Add the battery.
5. Close the circuit.
6. Observe both LEDs.

Students then disconnect one LED and observe what happens to the other.

Ask:**Does the second LED still have a complete pathway back to the battery?**

Students use their observations to compare this result with what happened when an LED was disconnected from the series circuit.

Part 5: Compare the Three Circuits

Characteristic	Simple	Series	Parallel
Number of LEDs	1	2	2
Number of pathways	1	1	More than 1
Did the LEDs illuminate?			
What happened when the pathway was opened?			
What happened when one LED was disconnected?	N/A		
Other observations			

Place the **Simple, Series, and Parallel Circuit Worksheets** next to one another.

Have students compare the pathways they constructed.

Discuss:

What is similar about all three circuits?

What is different about the series and parallel circuits?

Why does every working circuit still need a complete pathway?

Which circuit would you choose if you wanted to create a card with more than one LED? Why?

The last question serves as the transition into Lesson 2.

Part 6: Transition to the Design Challenge

Explain to students: **Today, the circuit pathways were already designed for you. Next, you will become the engineer.**

In Lesson 2, students will design an original light-up card. Unlike the worksheets used in Lesson 1, students will need to decide:

- Where to place the battery
- Where to place the LED or LEDs
- Where the copper tape should travel
- How to create a complete circuit
- Whether to use a simple, series, or parallel arrangement
- How the circuit will be incorporated into the artwork

Encourage students to keep the three completed circuit worksheets available during Lesson 2. They can use them as models when planning and troubleshooting their own circuits.

Teacher Tip

Do not throw away unsuccessful circuits.

A circuit that does not illuminate immediately provides an opportunity for students to troubleshoot.

Instead of fixing the circuit for the student, ask:

- Is your circuit open or closed?
- Can you trace the entire pathway with your finger?
- Are your LED leads facing the correct direction?
- Does each LED have a complete pathway to the battery?
- Where might the connection be interrupted?

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Lesson 2: Paper Circuit Card Design Challenge

Lesson Overview: In Lesson 1, students constructed simple, series, and parallel circuits using the provided circuit worksheets. In Lesson 2, students apply what they learned by designing and constructing their own **light-up paper circuit card**.

Unlike Lesson 1, the circuit pathway is no longer provided. Students must determine where to place the battery, LED or LEDs, and copper tape to create a functional circuit that is incorporated into an original card design.

This lesson allows students to apply their understanding of **open and closed circuits, polarity, series and parallel circuits, and troubleshooting** while engaging in the engineering design process.

Learning Objectives: By the end of the lesson, students will be able to:

- Design a functional paper circuit.
- Create a circuit diagram before beginning construction.
- Correctly position the positive and negative sides of an LED and battery.
- Construct a closed circuit using copper tape, LEDs, and a coin-cell battery.
- Select an appropriate circuit arrangement when using multiple LEDs.
- Test and troubleshoot a circuit.
- Revise a design based on testing and observations.
- Incorporate an electrical circuit into a creative final product.

Materials

Per student or pair:

- Cardstock or heavy paper
- Conductive copper tape
- 1 coin-cell battery
- 1–3 LEDs
- Pencil
- Ruler
- Scissors
- Clear tape
- Markers, colored pencils, or other decorating materials
- Paper Circuit Card Planning Sheet
- Completed circuit worksheets from Lesson 1 for reference

Part 1: Introduce the Design Challenge

Present students with the challenge:

> **Design and construct a paper card that uses a working electrical circuit to illuminate part of your artwork.**

Show students an example of a completed light-up card.

Discuss how the LED is not simply attached to the card but is intentionally incorporated into the design.

Possible ideas include:

- Birthday cake with a glowing candle
- Firefly
- Lighthouse
- Robot with glowing eyes
- Night sky with illuminated stars
- Vehicle with headlights
- Holiday card
- Flower with a glowing center
- Science-themed card

Students can create any appropriate design as long as the LED is incorporated into the artwork and the circuit functions.

Remind students that the **Simple, Series, and Parallel Circuit Worksheets from Lesson 1** can be used as references while they plan their circuits.

Part 2: Design the Front of the Card

Before constructing the circuit, students should decide what they want their finished card to look like.

Have students sketch their idea on the **Paper Circuit Card Planning Sheet**.

Students should identify:

- What their card will depict
- Where the LED or LEDs will appear
- How the light will become part of the artwork
- Whether they plan to use one LED or multiple LEDs

Teacher Tip

Encourage students to keep their first design relatively simple. Students can always add complexity after they successfully construct their first working circuit.

Part 3: Plan the Circuit

Once students know where their LED will be located, they plan the circuit that will be hidden inside the card.

Students should mark:

- Battery location
- Positive side of the battery
- Negative side of the battery
- LED location
- Positive LED lead
- Negative LED lead
- Copper tape pathways

If students are using multiple LEDs, they should also determine whether they will use a **series or parallel circuit**.

Encourage students to refer back to the completed worksheets from Lesson 1 when planning their pathway.

Teacher Checkpoint

Before students receive copper tape, quickly review their circuit plans.

Ask:

- **Is there a complete pathway?**
- **Where will your battery go?**
- **Where is the positive pathway?**
- **Where is the negative pathway?**
- **Is your LED facing the correct direction?**
- **If you have multiple LEDs, are they arranged in series or parallel?**

It is much easier for students to correct a pencil drawing than to remove and replace copper tape.

Part 4: Construct the Paper Circuit

Once the plan has been checked, students begin construction.

Step 1: Add the Copper Tape

Students place copper tape along the pathways they drew.

Whenever possible, students should use continuous pieces of copper tape.

At corners, students can carefully fold the copper tape rather than cutting it. This helps maintain good electrical connections.

Remind students that the positive and negative pathways should **not touch each other directly**.

Step 2: Add the LED

Students position the LED where they planned.

Remind students:

Long LED lead = Positive (+)
Short LED lead = Negative (-)

The leads should make firm contact with the copper tape.

Clear tape can be used to help hold the LED in place.

Step 3: Add the Battery

Students position the coin-cell battery at the end of the circuit.

Have students identify the + symbol on the battery before placing it.

The positive side of the battery should connect with the positive pathway, while the negative side should connect with the negative pathway.

Step 4: Close the Circuit

Students press or fold the battery connection so that both sides of the circuit make contact with the battery.

The LED should illuminate when the circuit is closed.

Students should be able to release the connection to open the circuit and turn the LED off.

Part 5: Test and Troubleshoot

Students should test their circuit **before completing the artwork**.

If the LED illuminates, they can move forward.

If it does not illuminate, remind students that troubleshooting is part of the engineering process.

Students should use the concepts they learned in Lesson 1 to determine why the circuit is not working.

Paper Circuit Troubleshooting Checklist

1. Is your circuit closed?
Trace the entire pathway with your finger.

Battery → Copper Tape → LED → Copper Tape → Battery

Look for gaps.

2. Is the LED facing the correct direction?
Check the positive and negative leads.

3. Is the battery facing the correct direction?
Check the + side of the battery.

4. Are the LED leads touching the copper tape?
Both leads need a firm connection.

5. Is there a break in the copper tape?
Pay special attention to corners and places where pieces overlap.

6. Are the positive and negative pathways touching?
They should not directly cross or touch.

7. Does the LED work?
Test the LED directly against the battery.

Teacher Tip

Try not to immediately repair a student's circuit.

Instead, ask questions such as:

- Can you trace the complete pathway?

- Is this circuit currently open or closed?
- Where might the pathway be interrupted?
- Which side of your LED is positive?
- What is one change you could make and test?

Students should make **one change at a time**, test the circuit again, and determine whether that change solved the problem.

Part 6: Complete the Card

Once students have successfully tested their circuits, they can complete the artistic portion of their cards.

Students may use markers, colored pencils, construction paper, stickers, or other available craft materials.

Encourage students to make the LED an intentional part of the artwork.

For example, rather than simply drawing a flower next to an LED, the LED could become the **center of the flower**.

The finished product should demonstrate both **function and creativity**.

Part 7: Test, Share, and Reflect

Have students demonstrate their completed cards to a partner.

The partner should examine the card and try to identify:

- Power source
- Conductive pathway
- LED
- How the circuit opens and closes
- Whether the circuit is simple, series, or parallel

Students then complete a brief reflection.

Student Reflection

1. What type of circuit did you use in your card?

- ☐ Simple
- ☐ Series
- ☐ Parallel

2. Describe how electricity travels through your circuit.

_____

_____

3. What happens when your circuit is opened?

_____

4. Did your circuit work on the first attempt?

- ☐ Yes
- ☐ No

5. If not, what problem did you find?

_____

6. What did you change to make your circuit work?

_____

7. What would you change or add if you created another paper circuit?

_____

_____

Lesson Closure

Bring students together with their completed cards and ask:

How was designing your own circuit different from building the circuits on the Lesson 1 worksheets?

Discuss how Lesson 1 provided the circuit pathways, while Lesson 2 required students to make their own design decisions.

Emphasize the engineering process students used:

Plan → Build → Test → Troubleshoot → Redesign → Test Again

A successful project is not necessarily one that worked on the first attempt. Troubleshooting and improving an initial design are important parts of engineering.

Extension

After students successfully complete their first paper circuit card, the project can be expanded by challenging students to:

- Add additional LEDs.
- Convert a simple circuit into a parallel circuit.
- Design a different type of paper switch.
- Create a light-up poster or model.
- Incorporate a small motor into a future project.
- Design an interactive paper circuit related to another subject area.

The card provides students with a foundation that can be used for increasingly complex electronics and engineering projects.

Troubleshooting Paper Circuits

Troubleshooting is an important part of the engineering process. Students should be encouraged to investigate their circuit before assuming that the materials do not work.

Problem: LED Does Not Illuminate

Check 1: Polarity

Is the LED facing the correct direction?

Try reversing the battery.

Check 2: Complete Pathway

Trace the circuit from:

Battery → copper → LED → copper → battery.

Is there a gap anywhere?

Check 3: Copper Connections

Are two pieces of copper tape overlapping but failing to make good electrical contact?

Press connections firmly.

Check 4: LED Contact

Are both LED leads making firm contact with the copper tape?

Check 5: Battery Contact

Is the battery touching both pathways correctly?

Check 6: Short Circuit

Are the positive and negative copper pathways accidentally touching?

Check 7: Components

Test the LED directly against the battery.

If it still does not illuminate when oriented correctly, try another LED or battery.

Teacher Tip: Don't Fix It!

When a student's circuit does not work, avoid immediately repairing it.

Instead ask:

- Where should the electricity travel?
- Can you trace the complete pathway?
- Where might the pathway be interrupted?
- Which side of your LED is positive?
- Which side of your battery is positive?
- What is one thing you could change and test?

Troubleshooting is part of the learning experience.

Extensions and Adaptations

One of the advantages of paper circuits is that the basic circuit can be incorporated into many different projects.

Light-Up Science Diagrams

Students can add LEDs to diagrams such as:

- Solar systems
- Human body systems
- Food webs
- Cells
- Ecosystems
- Maps
- Energy diagrams

Interactive Posters

Students create informational posters where LEDs highlight important information.

Paper Circuit Vocabulary

Students create an illustration representing a science or engineering vocabulary term and incorporate an LED into the design.

Engineering Challenge

Provide students with a limited quantity of copper tape and require them to create a working circuit within the material constraint.

Switch Design

Challenge students to create their own paper switch that allows the circuit to be turned on and off.

Possible solutions include:

- Folded paper tabs
- Pressure switches
- Pull tabs
- Paper clips

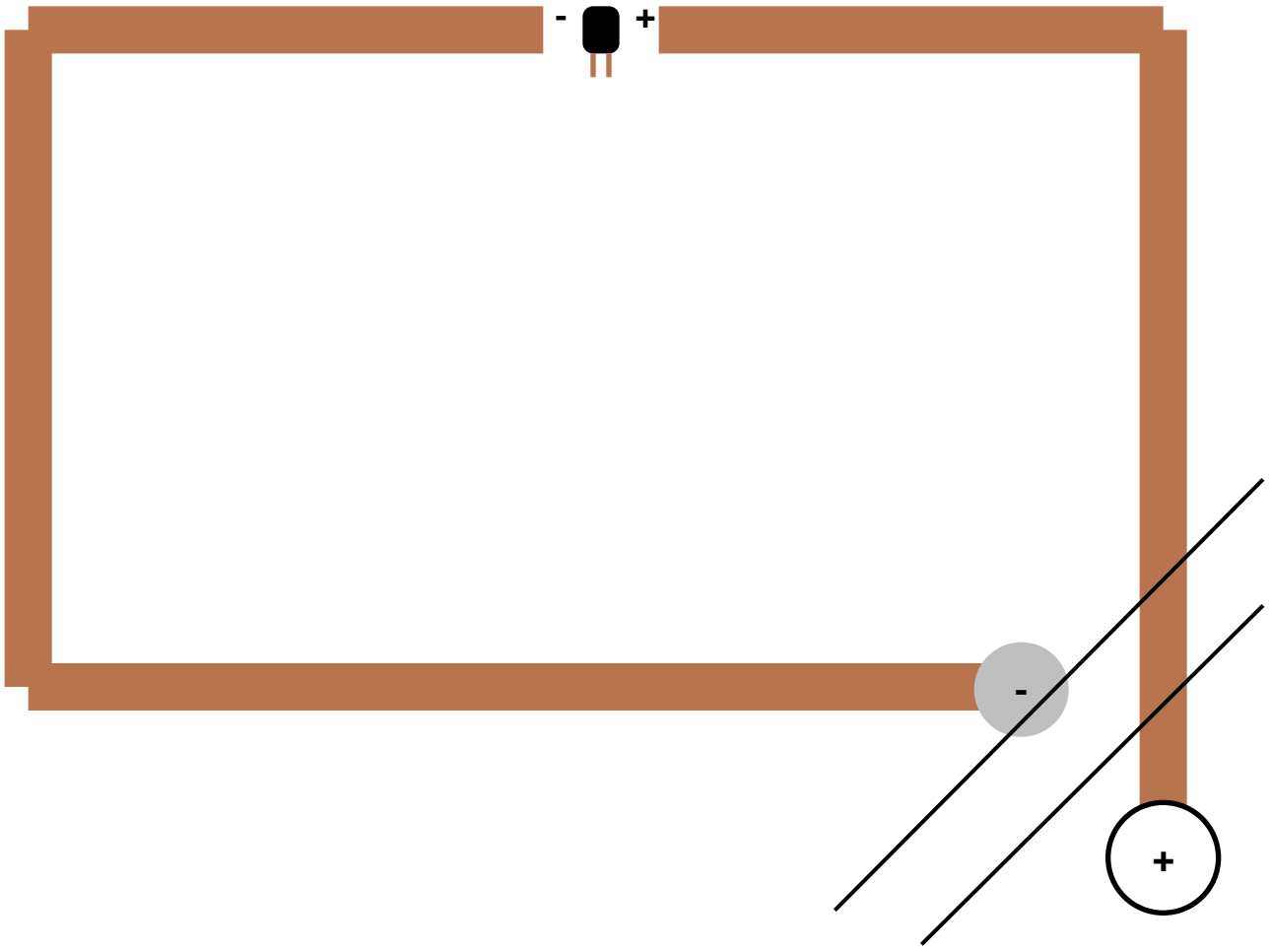
Motors and Motion

Once students understand basic circuits, small motors can be incorporated into future projects.

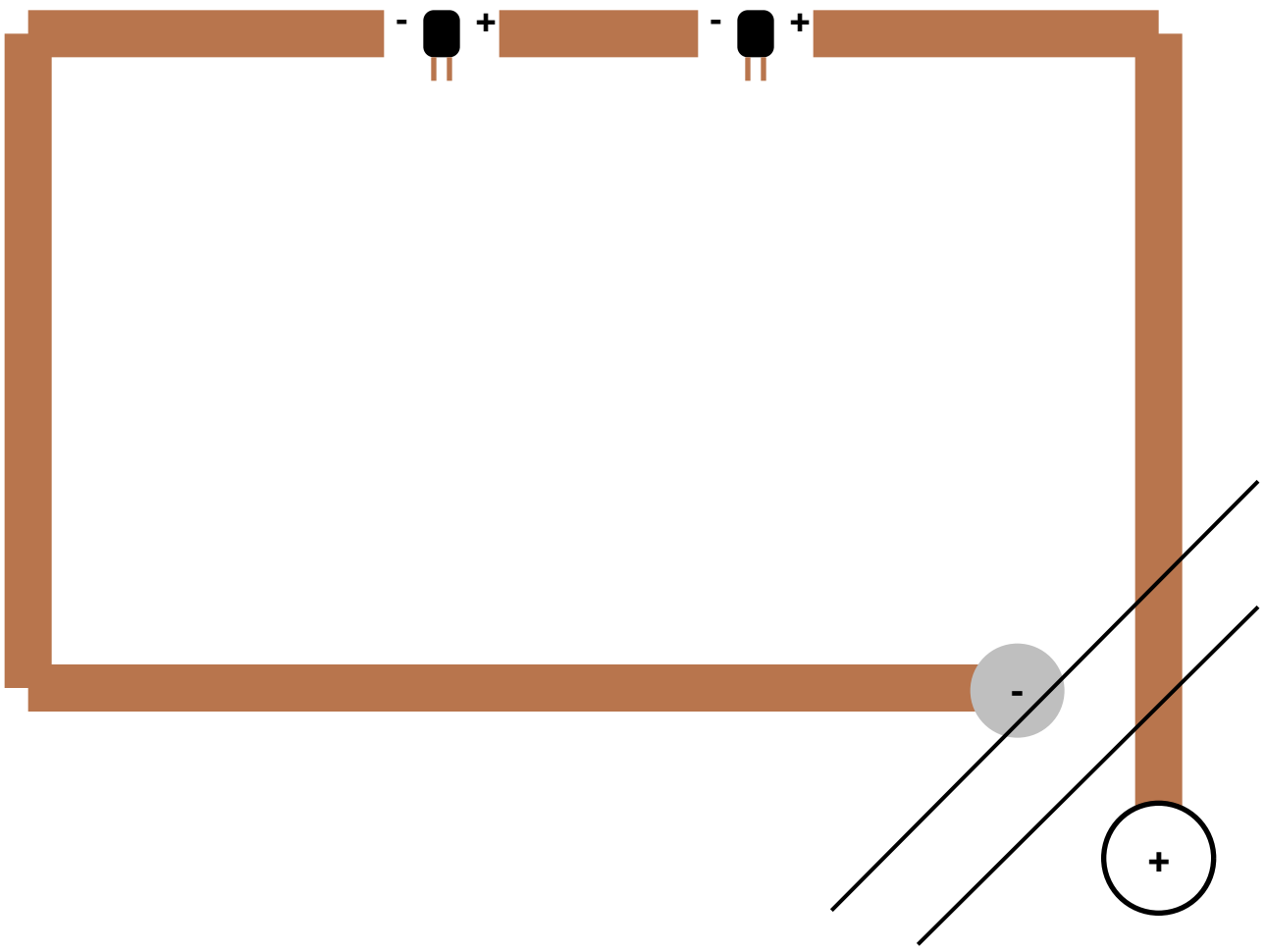
Students can explore how electrical energy can produce motion rather than light.

This provides a natural transition from paper circuits into more complex engineering, electronics, or robotics activities.

Simple Circuit



Series Circuit



Parallel Circuit

