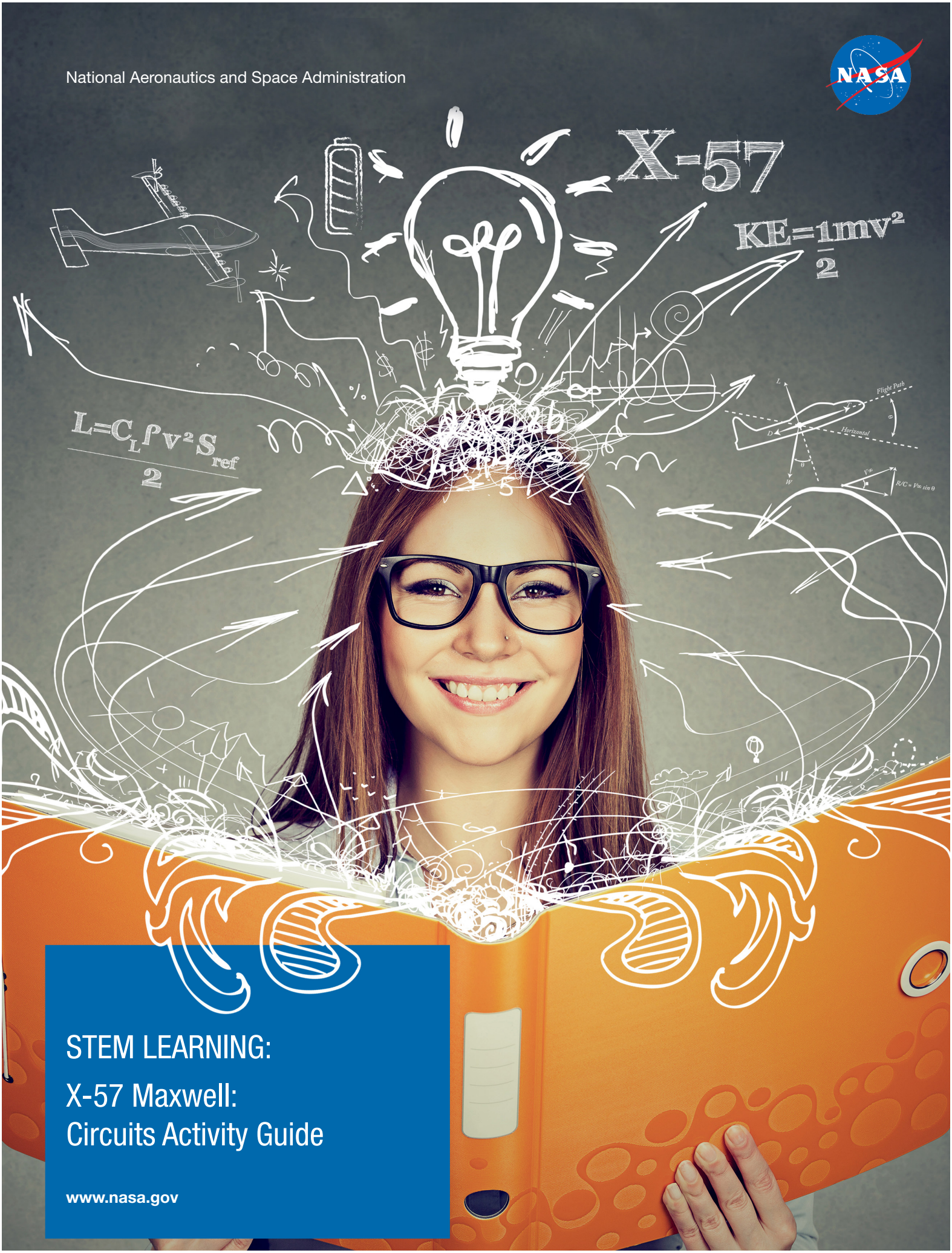
National Aeronautics and Space Administration



STEM LEARNING:

X-57 Maxwell: Circuits Activity Guide

www.nasa.gov

WHAT IS THE X-57?

NASA's X-57 Maxwell is a small, experimental aircraft powered completely by batteries. It is NASA's first full-sized all-electric experimental aircraft, or X-plane. Compared to standard fuel-powered airplanes, the X-57 is designed to have increased high-speed cruise efficiency, zero in-flight carbon emissions, and flight that is much quieter for the community on the ground.

One of the primary goals of the X-57 project is to develop all-electric technology that will make flying cleaner, quieter, and more sustainable. The technologies and verification and testing processes created for the X-57 will be an important part of future projects that work towards more sustainable aviation.

The X-57 requires banks of batteries to produce enough electricity to power its fourteen wing-mounted engines. There is an extensive electrical distribution system that distributes electricity to each motor.

Figure 1. This artist's rendering shows the X-57 in flight. Credit: NASA

HOW DOES ELECTRICITY GET FROM THE BATTERIES TO THE MOTORS?

Electricity is the flow of electrons, one of the sub-atomic particles that make up atoms. Electrons flow through a material called a conductor. Conductors make up the wiring in the X-57 that carries electricity through electric circuits, to the different parts of the plane.

Batteries, like the ones in the X-57, need to be attached to an electric circuit for electricity to flow and do work. A simple electric circuit is a complete path that includes a power source, conductive material, and an item that requires energy, such as a light, a motor, or another instrument. In this activity, you will be creating an electric circuit powered by a battery that will light an LED or LEDs.

What are the parallel and series circuits?

In the activity below, you will build a light-up paper helicopter by creating a "paper circuit" that uses copper foil tape, at least one LED, and a battery. If you are including more than one LED, you need to make sure that electricity passes through each one. There are two different ways that a circuit can pass electricity through both LEDs (or any other loads connected to a circuit)—a series or a parallel circuit.

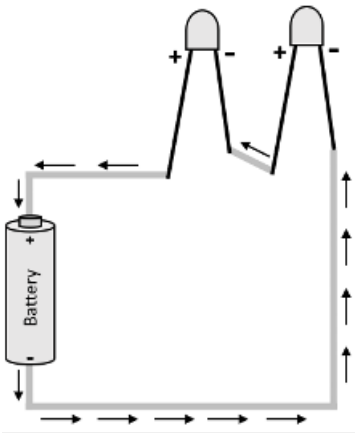


Figure 2. The arrows show the only path through which electricity can flow in a series circuit.

In a series circuit as shown in *Figure 2*, electricity flows out of the battery, through the first LED, through the second LED, then back to the battery to complete the circuit, following one pathway. In this type of circuit, if one of the LEDs breaks or becomes disconnected, or if the circuit is broken, both LEDs will not light.

In a parallel circuit as shown in Figure 3, electricity flows out of the battery then flows through each of the LEDs separately. In other words, there are now two different pathways electricity can take to get back to the battery. In this type of circuit, if one of the LEDs stops working, electricity can still flow through the second LED, meaning the second LED will still light.

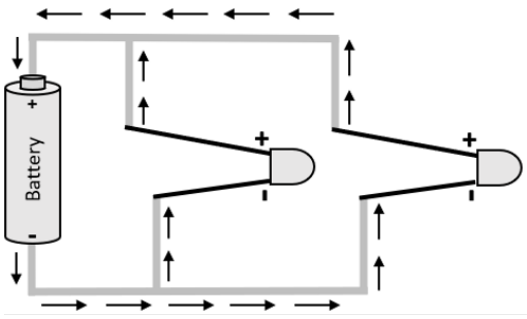


Figure 3. The arrows show both paths through which electricity can flow in a parallel circuit.

STUDENT ACTIVITY

In this activity, you will be making a paper helicopter that lights up.

Each student or group needs:

- Helicopter template
- 16.25” (or longer) strip of double-sided conductive copper foil tape (1/4” width)
  Note: *You can also use single-sided conductive copper foil tape but will need to add an extra step if using this kind of tape and will need a slightly longer piece. Double-sided copper foil tape is conductive on both sides—single-sided copper tape does not have conductive adhesive, so it is only conductive on one side.*
- (2) 5 mm LEDs (you can add 1 or 2 LEDs to the helicopter)
- CR2032 battery
- Ruler
- Scissors
- Paperclip or small binder clip

Each group will:

1. Cut around the outer rectangle of the helicopter.

2. Cut along each of the 3 solid lines. Do NOT cut along the dashed lines!

3. Cut the piece of copper tape into pieces of the following lengths (if using single-sided tape, you will have two longer pieces of tape. One piece should be 7” and the second should be 8.75”):

   - One (1) 3.25” piece (A)
   - Two (2) 2.75” pieces (B)
   - One (1) 2.5” piece (C)
   - One (1) 1.25” piece (D)
   - One (1) 1” piece (E)
   - One (1) 0.75” piece (F)
   - Four (4) 0.5” pieces (These will be used to connect the LEDs in step 9. You need 4 pieces if you are adding 2 LEDs, but only 2 pieces for 1 LED.)

4. For each piece of copper tape (except for the four 0.5” pieces), peel off the adhesive backing and place it on the helicopter template as shown in *Figure 4*. Make sure the copper tape is securely affixed to the

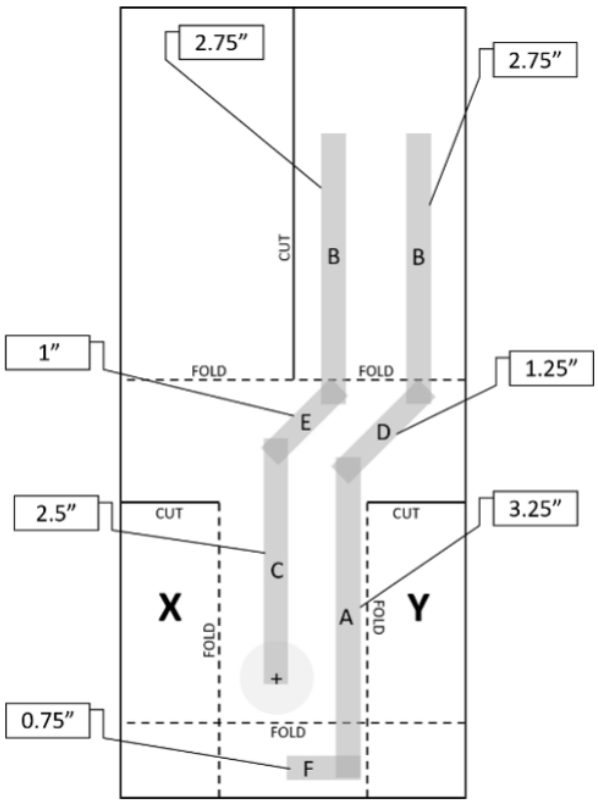


Figure 4. The locations for the pieces of copper tape are shown.

paper and that each piece of tape covers the other piece of tape. *If using single-sided copper tape, you will need to fold the tape at circuit corners to ensure the sticky side faces down.*

5. Fold the flaps labelled X and Y towards the back as shown in *Figure 5*. The fold should be on the dashed lines. Run your finger down the fold to make sure the crease is tight.

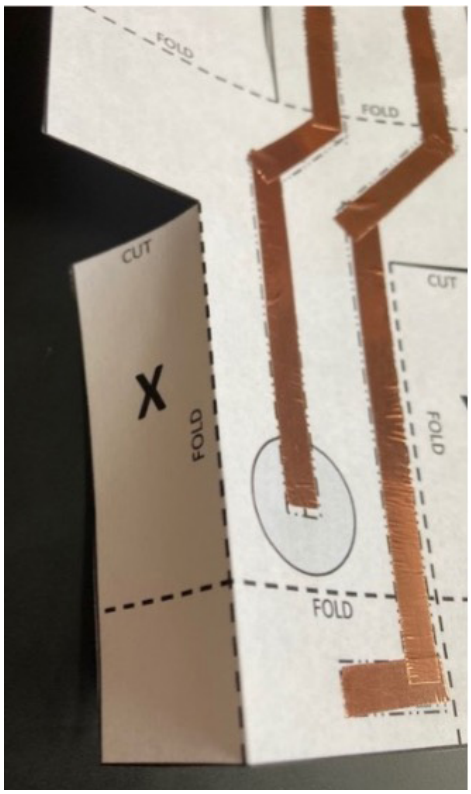


Figure 5. Fold flaps X and Y back.

6. Look at the LEDs. You can add one or both to the helicopter. *See Figure 6* for placement. The LED wires will connect the two copper tape strips, completing the circuit. Note that each color LED needs a different amount of electricity, so it is best to have both LEDs the same color. It is possible to use two different colors, but you will have to experiment with color combinations to see which colors work best.

7. LEDs are polar, meaning they have a positive and negative side. To figure out which side is positive and negative, each LED has two wires: a long wire and a short wire. The long wire must be connected to the positively charged copper tape strip while the shorter wire must be connected to the negatively charged copper tape to allow electricity to flow.

8. Bend the wires outward so that each wire overlaps one of the copper tape lines on the helicopter blade. *See Figure 6 for an illustration*. The circuit shown is a parallel circuit so that electricity can flow through each LED independently.

9. Place the LED with the long wire to the left and the short wire to the right. Use 0.5” pieces of copper tape to connect each wire to the appropriate strip of copper tape (*see Figure 6*).

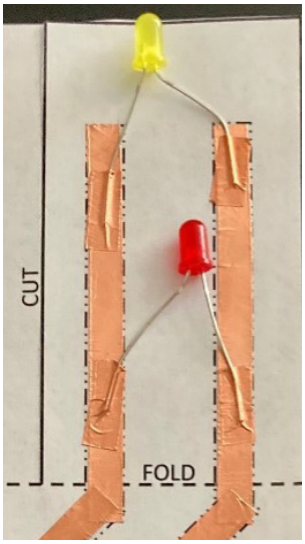


Figure 6. Use the 0.5” pieces of copper tape over the LED leads to connect the LEDs to the circuit.

- If you are unable to identify the long and short wires of the LED, a quick internet search can show you other ways to identify the positive and negative ends of the LED. Similarly, this can be tested before taping the LED(s) to the paper; if the LED does not light up when connected to the battery, flip it around and it should work.

10. If attaching two LEDs, repeat steps 8 and 9 with the second LED.

11. Place the CR2032 battery on the circle on the helicopter template. It is important that the positive side of the battery is down (touching the paper and tape). To determine which side of the battery is positive, look closely at the face of the battery to see which side is marked as positive with a +.

12. Fold the bottom of the helicopter towards the front along the dotted line, creating a pocket for the battery, so that the circuit is completed. The LED(s) should light up as long as both pieces of copper tape are touching the battery.

13. Put a paperclip or small binder clip on the bottom of the helicopter to help keep the circuit intact. *Figure 7* shows what your helicopter should look like for steps 4-13.

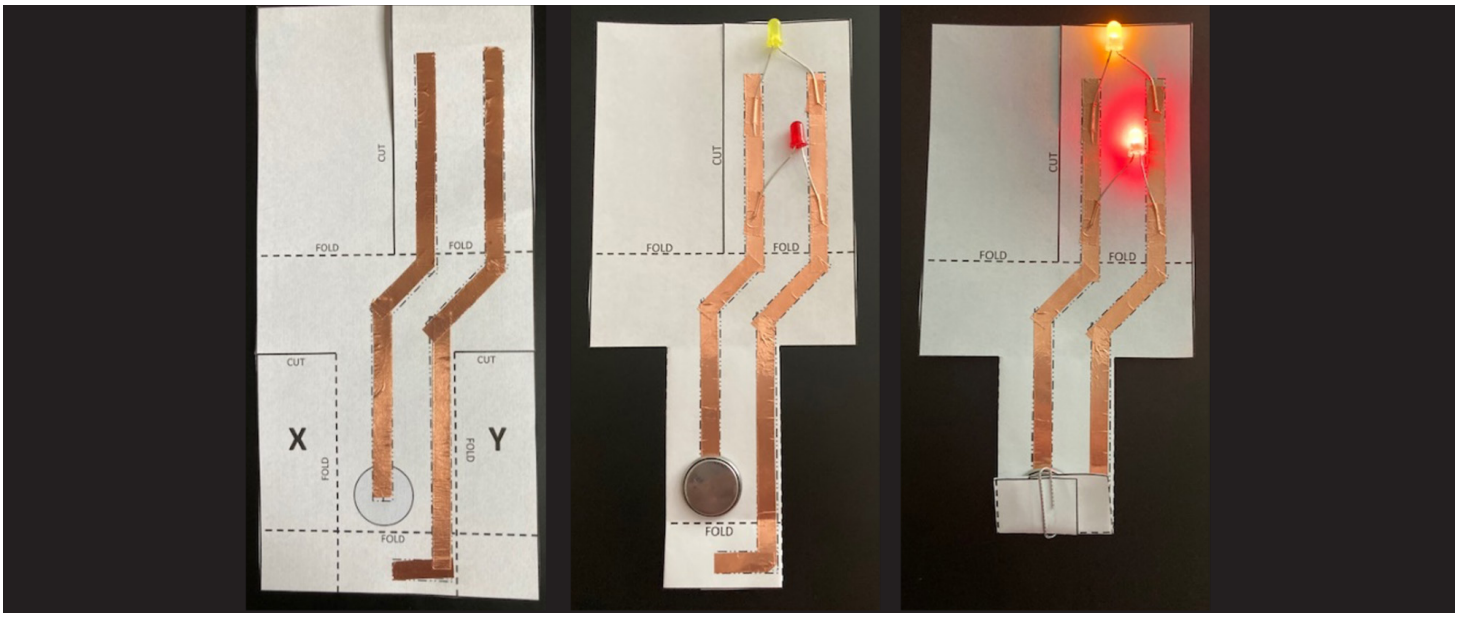


Figure 7. The different steps of making the paper helicopter are shown.

14. Fold the two blades in opposite directions along the dashed lines. For the blade that has copper tape on it, make sure the tape is facing upward. The blades should look like the ones shown in Figure 8.

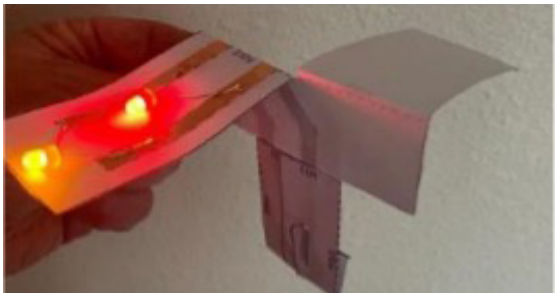


Figure 8. The completed helicopter is shown.

TROUBLESHOOTING

If your LEDs do not light up once you have completed the circuit, use the following suggestions to find the problem:

- Check all connections - around the LED leads, alignment with the battery, any broken places in the copper tape – and use more tape to reinforce connection if necessary. Push down on the tape to make sure it is properly adhered to both paper and to other pieces of tape. There should be plenty of overlap with pieces of tape to ensure a solid circuit, but the positive side should not touch the negative side as that would create a short circuit.

- Make sure you have a complete, proper circuit. The positive end of the LED(s) must match up with the positive end of the battery. One piece of copper tape should make solid contact with one side of the button battery and the second piece of copper tape should make solid contact with the other side of the battery once folded.

    - Flip the battery over. If the LED was put in backwards, it means the positive and negative parts of the circuit are reversed. If using two LEDs, make sure both LEDs are oriented the same (both negative sides are touching the same piece of copper).

- Sometimes an LED or battery might not be working correctly, so try a different battery and/or a different LED.

- Directions provided are for double-sided conductive copper foil tape, which can be purchased from a number of online retailers. Because this type of tape is conductive on both sides, sticking one piece on top of another creates an electrical connection.

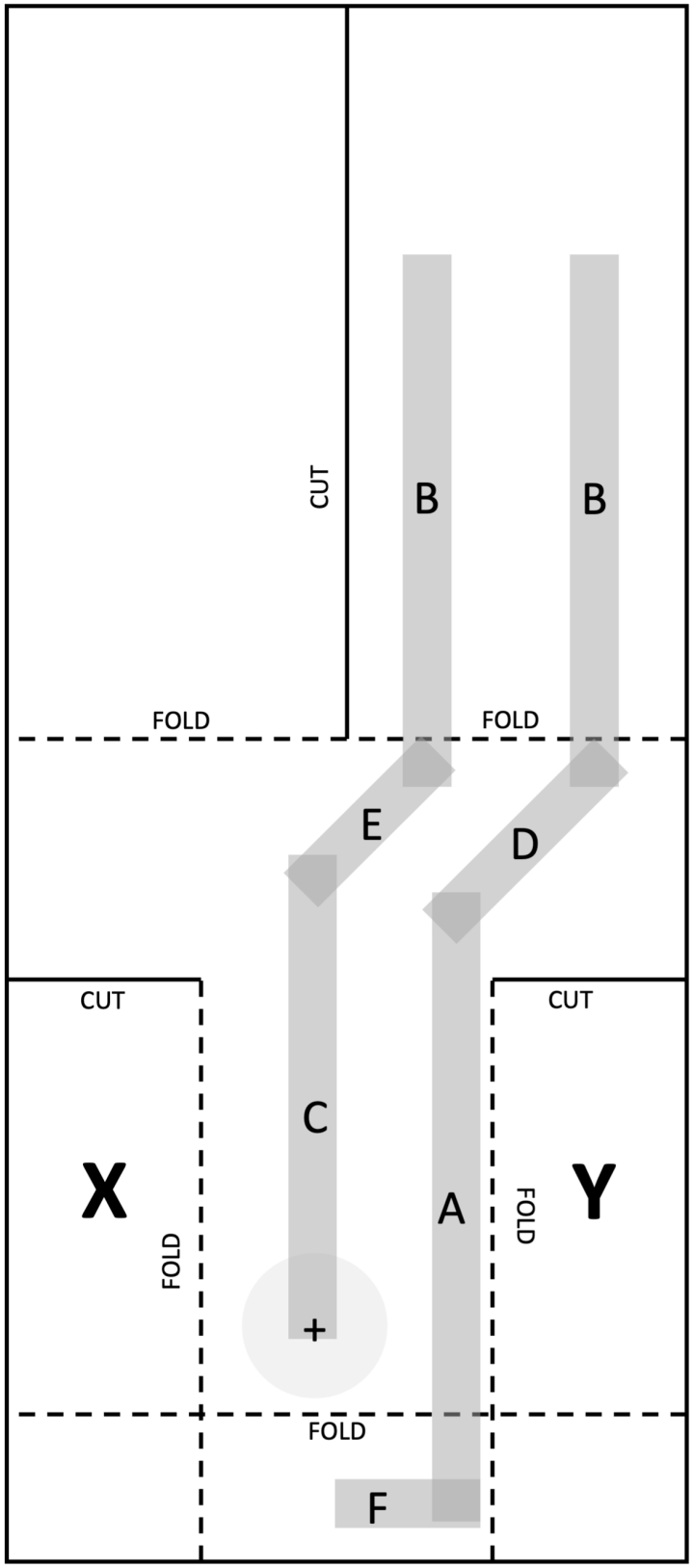
If you get copper foil tape that is only conductive on one side, you will need to have one piece of tape that goes all the way from the battery to the LED. To do this, you will need to create folds where the tape changes direction. An internet search will provide you with directions on how to do this.

SUGGESTIONS FOR FURTHER EXPERIMENTATION

- You can try adjusting the circuit by using different numbers, colors, or sizes of LEDs. You can also use different sizes of button batteries. LEDs are commonly found in 3 mm, 5 mm, and 10 mm sizes. The smaller sizes will have less mass, and the larger ones will have more mass.
- There are different types of LEDs available that you can also use. They are made as wearable “lilypad”-type LEDS, stickers, and more. You can even use LEDs from strings of lights.
- You can also adjust the helicopter itself to change the speed with which it rotates and falls. Try folding or cutting the blades to change their shapes. You can also try folding the blades at different angles.
- Using different paper can change your helicopter as well. You can use larger paper to change the overall size of the helicopter. Or you can print it on heavier paper like cardstock.
- Try adding more weight to your helicopter. This can easily be done by adding additional paperclips to the bottom of it.
- Can you use other conductive material to make a circuit? Lots of materials are conductive, so try to create a different type of circuit. You could try electrically conductive paint or a conductive pen.
- Can you connect two LEDs in a series circuit so that they both light up?
- Can you think of anything else that you could change? Have fun experimenting with different aspects of the helicopter and/or circuit. The possibilities are limitless!

PAPER CIRCUIT HELICOPTER TEMPLATE

Cut on the solid lines and fold on the dashed lines.



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