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Circuit Card Company Consultation Report

Background: The Circuit Card Company (CCC) has been making its light-up LED cards using copper tape. The tape works well but is time consuming to apply. The company has just acquired a screen-printing machine that it believes will speed up the card making process. It has contracted with your engineering firm to design a new card using stencils and conductive paint.

Your job is to produce a prototype and report!

Step 1. Reverse Engineering: How does an existing CCC card work?

With a partner, carefully reverse-engineer an existing Circuit Card Company copper tape card circuit to see how it works. Write your answers to the questions below.

a. How do you turn the circuit on?

b. What prevents the circuit from being on all the time?

Carefully take the circuit apart by opening it and untaping one side.

c. Which side of the battery is pointing down (positive or negative)?

d. Is the battery completely taped over or is most of it exposed?

Look closely at an LED.

e. Which LED wire in the circuit is connected to the copper tape in contact with the positive side of the battery?

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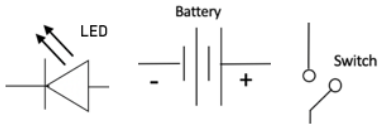
Draw a picture of the circuit below. Carefully note which side of the battery is positive and which LED wire is attached to the positive side of the battery.

Try drawing the circuit using the following symbols for each part.



The circuit does not work when the card is open.

f. When the cardstock is closed and you push down on the card, how does the copper tape on the left side connect to the negative side of the battery?

g. What does this tell you about how the two pieces of conductive tape need to be positioned on the cardstock with respect to the battery?

Notice that the pieces of scotch tape holding the LED wires completely covers them and that the two LED wires do not touch.

h. Why do you think this is important?

Notice that there is a hole for the LED and a pen mark on the inside right side.

i. Do you think they are related?

j. Do you think they might be important for the card construction and tape alignment?

Step 2. Conductive Paint Prototype: Painting.

Now that you understand how this circuit works, go to the resource table to design and make a sample card using a conductive paint. Each student should complete her/his own.

[**Optional Extension 2:** The company wants a complete card; the front cover will be a LED circuit that can be pushed on, and then the larger card will open for a message inside.]

HELPFUL HINTS

- Make sure your stencil is sticking tightly and smoothly to the cardstock before you apply the paint.
- Apply a thin coat of paint and LEAVE THE STENCIL ON UNTIL THE PAINT DRIES (ABOUT 15 MINUTES).
- A blow dryer may help the card dry faster.

Step 3 Assembling the Prototype.

First put a battery in between a LED to make sure that both work. You'll notice that the LED allows electricity to flow in one direction only. That is what a DIODE does. LEDs emit light. That is why they are called **L**ight **E**mitting **D**iodes.

Put your complete card together. Does it work? If not, go over your observations from Step 1 with your partner or look at a CCC copper tape card to make sure you have assembled the card correctly.

Step 4. Optional Extension 1: Resistance Measurements

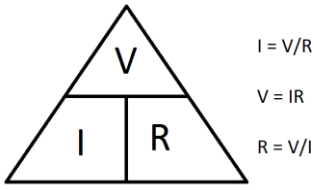
The brightness of the LED depends on how much current is going through it. This in turn depends on the voltage of the battery and how easily the "wires" between the battery and the LED allow electricity to flow. This last quality is called the "resistance" of the wire. Using a multimeter measure the resistance of the copper tape. Set the multimeter at the 200 Ω (Ohm) scale and put the leads at either end. *Record your measurements below:*

Copper Tape Resistance _____

Copper Tape Current _____

Conductive Paint Resistance _____

Conductive Paint Current _____



We can calculate the current using an equation called *Ohms Law.*

Current (I, amps) = Voltage (volts) /Resistance (ohms) = _____

Look at (or measure) the voltage of your battery and calculate the current (I) that goes through the LED using the copper tape.

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When your prototype dries measure the resistance of a conductive paint trace from two ends. You may need to turn the dial to the 2000 Ohm scale if you are using black carbon paint. *Calculate the current going through your circuit and record it above.* (The paint takes 24 hours to completely dry and reach its best conductivity - lowest resistivity). If project time allows, wait 24 hours to get a more accurate reading.

1. Why do you think the meter jumps around so much?

2. Which material has the most resistance, the copper tape or the conductive paint?

3. What does this mean in terms of LED brightness?

4. Assuming the brightness is proportional to the current flow how much brighter is the copper tape?

$$\frac{\text{Copper Tape Current}}{\text{Conductive Paint Current}} = \boxed{}$$

5. Can you see the difference?

Step 5. Optional Extension 3: Two-LED Card.

CCC now wants you to design a card for two LEDs and one 3-volt battery. Using the circuit elements attach 2 LEDs in series (1 path) and then try 2 in parallel (2 paths).

- Which configuration made the brightest LEDs?

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Draw a card design for a 2 LED circuit.

Try out your design using copper tape. **Does it work?**