Conductivity

Learning Objectives	1) Students will create simple and complex circuits using conductive ink.
Time	30-40 minutes
Topics	1) Basics of circuit design, including components of circuits and troubleshooting. 2) Conductivity of real world materials. 3) Function of transistors.

Before the Lab:

Supplies to buy every time you run the activity:

1) none

Supplies to buy once:

1) Materials with various conductivity. Examples include:
    1) Rubber bands
    2) Metal wire
    3) Yarn
    4) Pipe cleaners
    5) Paper clips
    6) Tin foil
    7) Cardboard
    8) Fabric

Supplies to buy as needed: You shouldn't need to replace the components often. The pens should last 3-5 iterations of the lab:

1) Plain paper for scratch paper.
2) One CircuitScribe Basic Classroom Kit per 20 students. If you need to replace individual kits, do so here.
3) One CircuitScribe Super Kit per 4 students. If needed, you could make do with one kit per 10 students if you stagger the advanced activities among the groups.
4) Buy extra conductive ink pens here.

Prior Knowledge Recommended for Instructor:

1) Familiarity with basic electrical properties
    - Conductivity vs. resistivity
    - How to measure the resistance of a material and relate it to a material's conductivity.
2) Familiarity with Band Theory
    - If desired to include as a topic in the lecture.
3) Basic understanding of circuit design and transistors
    - Explain the difference between open circuit and short circuit conditions.
    - Understand how current flows through a transistor.

Prior Knowledge Recommended for Students:

1) Types of bonding: metallic, covalent, non-covalent, ionic
2) Understand difference between material classes by look and feel: ceramic vs. metal vs. polymer

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Lab Set-up:

We run the lab with groups of 5 students.

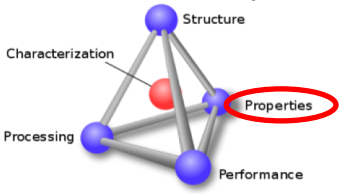
1) Before the students arrive, make sure each group has the following from the CircuitScribe Basic Kit:
   - One conductive ink pen
   - Circular stencil
   - BI-LED x2
   - 9 V Battery with battery adapter
   - Stainless steel sheet
2) After the concept check question in Basic Activity 1, give the group their NPN transistor
3) The Advanced Activities require the following:
   - Color Wheel: RGB LED
   - Light sensor: Photosensor
   - Blinking lights: Blinker

Give these to groups as needed. If a group is using them when another group comes to it, encourage the first group to try another advanced activity first.

Pre-lab Questions:

The lecture before this lab should explain the basics of electrical conductivity and how the type of bonding affects electrical conductivity. After lecture, students will answer and then discuss the following questions with each other.

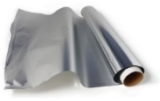
1) Electrical conductivity fits in the properties category of the tetrahedron. Please explain why it fits in the properties category.



Answer: Electrical conductivity is a material property. We observe how conductive a material is by seeing how well various materials conduct electricity in a circuit.

2) What type of bonding does each material have? What do the materials with high electrical conductivity (higher than 2×10^6 S/m) have in common? Why do you think that type of bonding is related to high electrical conductivity?

5.96×10^7 S/m
Copper



3.87×10^7 S/m
Aluminum

2.4×10^6 S/m
Titanium Alloy

$\sim 10^{-11}$ S/m
Silica

10^{-14} S/m
Polystyrene

Answer: Copper, Aluminum and the Titanium Alloy have metallic bonding. Silica and polystyrene both have covalent bonding. Materials with high conductivity tend to have metallic bonding. In metallic bonding, electrons are loosely bound and so are able to travel easily through a material under an applied voltage.

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Running the lab:

1) Split the students into groups of five.

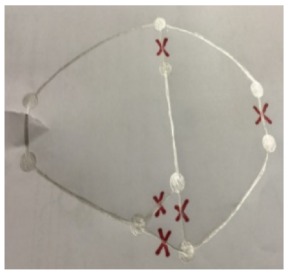
2) They should have already answered the pre-lab questions. Ask the students if they had any unresolved questions about the pre-lab questions.

3) Instruct the students to read all of the directions. At a certain point they will be asked to answer a concept/design check question. They will need to check their answer with a TA/instructor in order to get the NPN transistor needed for the second basic activity

4) Students should do the basic activities in order, but they can do the advanced activities in any order they choose.

Troubleshooting Circuits:

1) Too many lines: If students draw too many lines (e.g., the lines under the red **X** marks in the figure), then their circuit will not work properly. If students do this, they will either need to start their circuit over or create breaks in the extra lines (i.e., rip the paper to break the extra line).



Encourage students to think of the electrons as water flowing through a pipe. If you have many pipes, then the electrons will flow in all of the pipes and their circuit will not function as intended.

2) Not enough ink:

If the students don't make the lines thick enough, the electrons won't be able to conduct through the circuit very well. As a result, there won't be enough current (if any) to make the circuit work.

Encourage the students to remember the pipe metaphor. If there is a break in the pipe, how well will water flow through it? The goal is to get the students to make sure they have plenty of ink in both their circuit lines and in the connections from the circuit line to the components (e.g., BI-LED or NPN Transistor)

3) Didn't use stencil:

Using the stencil to draw the circles in the correct locations will make your circuit work better. Use the stencil to draw the circles for the BI-LED and NPN Transistor.

Girls Learning About Materials

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Concept Check:

The concept check here asks students what will happen if they instead of a gap they drew a line between the two circles and then placed objects over the gap. See the trouble shooting “Too many lines” section for an explanation.

After the students have explained their reasoning, give each group one NPN transistor. They will need it for Basic Activity 2.

Discussion points to cover after the activity:

1) Where will the current flow within the circuit if there are two paths: one where there is a gap in the wire and one where the wire is connected? Why?

2) Why is your body a conductor? Is it as good of a conductor as a metal? Why or why not?

3) Why do you need a transistor in your touch screen to use your finger as a conductor?