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| **Section of Lesson** | **1/1** |
| **Title** | Pencil Circuits!: Draw a Working Series and Parallel Circuit  |
| **Introduction**  | From the lamp on your nightstand to the complex smartphone in your pocket, electric circuits are all around us. In fact, without electricity, your body couldn’t function! In order to understand how everything from our bodies to computers work, students need to understand basic circuitry. This starts with learning how to create a closed circuit, add switches, and differentiate between series and parallel circuits. Students will use only paper, pencil, an LED, and a 9V battery to make their own circuits that will light a light emitting diode. Students are guided through their first circuit, and then prompted to draw their own circuit to build their knowledge through experimentation. The teacher will facilitate the learning by providing guiding questions to students.  |
| **Real Science Application**  | The Information Age relies on electrical circuits in almost every aspect of our lives. These circuits are often very complex, but are based on two types of circuits – series and parallel. Students in grades 6-8 will be introduced to the basic circuitry that is beneath all of the electronics we use every day. Scientists and engineers use their knowledge of electricity to design and build circuits that span hundreds of miles to circuits that can only be seen with the aid of a microscope.  |
| **Curriculum Alignment**  | NC Essential Standards

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| Content Area | Grade Level | NC SCS | Lesson 1 – *Pencil Circuits* |
| Science | 7 |  | **7.P.2.3** Recognize that energy can be transferred from one system to another when two objects push or pull on each other over a distance (work) and electrical circuits require a complete loop through which an electrical current can pass |
| Science | 6 |  | **6.P.3.3**Explain the suitability of materials for use in technological design based on a response to heat (to include conduction, expansion, and contraction) and electrical energy (conductors and insulators) |

Common Core Standards

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| Content Standard | Lesson 1 |
| ELA | Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. |

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| **Learning Outcomes**  | Students will create and design a series and parallel circuit that produces light using only a paper, pencil, 9V battery, and LEDs.  |
| **Time Required and Location**  | Two 50 minute periods (1 hr 40min total) |
| **Materials Needed**  | Teacher List* 1 “Pencil Circuits” worksheet per student
* 1 pencil per student
* 1 9V battery per student
* 2 LEDs per student
* Optional: Scotch tape

Student List\** 1 “Pencil Circuits” worksheet per student
* 1 pencil per student
* 1 9V battery per 2 students
* 2 LED’s per student
* Optional: Scotch tape
* Wi-Fi connected device with the ability to use Kahoot

\* May pair students for larger groups with smaller amounts of materials  |
| **Safety**  | 1. Do not connect LED directly to 9V battery (there is not enough resistance and it will cause the bulb to burn out)
2. When working with electricity, keep away from water and moisture.
3. When storing 9V batteries, ensure that the positive and negative leads are not touching other conductors, which would cause a short circuit and overheating.
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| **Student Prior Knowledge**  | This activity is designed to introduce electrical circuits to students. Students should have prior knowledge of atoms – specifically electrons—and conductors of electricity.  |
| **Teacher Preparations**  | **Groups:** * Students can work alone or in pairs to complete this activity

**The preparation list below is explained assuming each student is creating his own circuits****Classroom Arrangement:** * Students should have a clear area to work on this activity
* It would be helpful for the teacher to have a document camera to model the activity, but not necessary

**Preparation:** * View [http://www.youtube.com/watch?v=BwKQ9Idq9FM](http://www.youtube.com/watch?v=BwKQ9Idq9FM%20) to familiarize yourself with the activity’s concepts
* Copy at least one “Pencil Circuits” worksheet per student
* Extras are recommended for students that might make mistakes
* Have at least one battery for every two students (they can pass back and forth) when they are ready to test their circuits
* Have at least 2 LEDs per student
* Make sure each student has a graphite pencil
* Scotch Tape would be helpful to tape down the LED leads
* Day 2: Create a teacher account on [www.getkahoot.com](http://www.getkahoot.com)
* Search Kahoot for “Pencil Circuits”

**Suggestions:** * Emphasize that they need to draw very dark, thick lines for their conductors
* Understand that LEDs must be inserted into the circuit with the correct polarity. The longer lead of the bulb is the positive side that should be placed towards the positive side of the battery. The negative side of the LED is shorter and the bulb has a flat side.
* Let students experiment with designing their circuit layouts on the second problem. Guide them only as required.
* Depending on the specific bulb and conductivity of the pencil used, you may want to dim the lights to see the glow of the LEDs in the circuits
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| **Activities**  |

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| **Day** | **Task** |
| **DAY 1** | In pairs, have the students brainstorm for 30 seconds items that use circuits in their everyday life. Allow students to share their lists with the whole class. In pairs, have the students brainstorm for 30 seconds items that do not use circuits in their everyday life. Allow the students to share their lists with the whole class.Ask the students, “What are the parts of the circuits?” After allowing the students to share their ideas, distribute the handout **“Electric Drill”** to students and ask them to generate their own definition for each word. After a few minutes, share answers as a class and ask students to record correct definitions if they do not have them complete. *Make sure students have something comparable to the following definitions:* **Electricity** – the movement and interaction of electrons either naturally (lightning) or manmade (generators) **Conductor** – a substance or device that allows electricity to flow **Insulator** – a substance or device that does not allow electricity to flow **LED** – Light Emitting Diode **Battery** – a device that converts stored chemical energy to electric energy **Circuit** – a closed path that permits electric energy to flowHave the students list examples of conductor, insulator, and batteries. |
| After reviewing the definitions and examples as a class, instruct students that they will now create a working circuit to light up an LED light bulb. They will do this with only their pencil – no wires! Ask the students what they think the pencil lead will serve as in their preciously defined terms. |
| Provide students (either individually or in pairs) the following materials: 1. “Pencil Circuits” worksheet
2. 9V Battery
3. LED

\* You may want to distribute the batteries last so that students don’t get distracted from building the circuits.  |
| Ask for a volunteer to read the background aloud. Then, review the directions on the worksheet with the students. Emphasize that students must color in their conductive lines **very dark**! Only pencil will work for this!  |
| Allow students to color in and test their series circuit.  |
| Once they have successfully lit the LED bulb, they should complete step “d” and erase a small section of the pencil line. The bulb should turn off. This is exactly what a light switch does!  |
| Students may experiment with additional LEDs with any remaining time before the teacher collects the LEDs and batteries from students. Challenge the students to see who can cause the most LEDs to light. Remind students to bring their worksheet back to class for Day 2.  |
| **DAY 2** | Begin the class with a Kahoot quiz.You will need to create a teacher account on [www.getkahoot.com](http://www.getkahoot.com). Search for “Pencil Circuits” under “Students” for audiences. The Kahoot quiz made by akaufman should be one of the first few results. Students will go to www.kahoot.it and enter the code provided from the teacher account. This should be displayed on a projector.  |
| Have students take out their Pencil Circuits worksheets from yesterday. Review the information on Parallel Circuits and then show the following short video on Series vs. Parallel Circuits. * + <https://www.youtube.com/watch?v=apHkG4T6QHM>
	+ “Electricity - Series + Parallel Circuits”
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| Have students test the series circuit from previous day. Have students try to explain why this is a series circuit.Students will design and create a parallel circuit from scratch. This circuit must light two bulbs and be able to continue lighting one even if the other is removed. Distribute batteries and LEDs. *It should resemble this:* http://www.ats.edu.mx/proyectos/racevedo/Electricity/sample_files/image002.jpg\*The easiest way to lay out a parallel circuit is to draw rectangle and place the components between two sides (as shown above). Encourage the students to erase a section of the parallel circuit and test what happens. Suggest the students try to erase different sections of the parallel circuit and observe what happens. |
| Once students complete the parallel circuit, they should move on to the second page of the worksheet and answer the reflection questions. If students have time, encourage the students to try to devise a circuit that lights multiple LEDs. |
| End the class with a discussion of the activity and have students return their components. Collect worksheets for assessment. For a closing formative activity, have the students design series circuit and a parallel circuit and label each on an index card and turn it in when they are leaving class. |

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| **Assessment**  | Students will show their instructors their functioning circuits and then submit their Pencil Circuits worksheet for assessment.  |
| **Critical Vocabulary**  | **Electricity** – the movement and interaction of electrons either naturally (lightning) or manmade (generators) **Conductor** – a substance or device that allows electricity to flow **Insulator** – a substance or device that does not allow electricity to flow **LED** – Light Emitting Diode **Battery** – a device that converts stored chemical energy to electric energy **Circuit** – a closed path that permits electric energy to flow**Series Circuit** – only one possible route for electrons to flow through circuit**Parallel Circuit** – More than one path for electrons to flow (imagine a ladder with the outside leads supplying the power and the components between) |
| **Community Engagement**  | An engineer, especially an electrical engineer, would be an excellent coteacher and/or guest speaker for this activity. The engineer could discuss preparation to be an engineer (high school courses, college, internship, extracurricular activities, etc.), jobs, and projects worked on.  |
| **Extension Activities**  | * Research electric vehicles
* Research Power Generation
* Build your own capacitor
* Experiment with PhET’s online DC Circuit Simulator
* <http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc>
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| **Comments**  | * If you are not able to get the electronic components for this lesson plan, you may conduct the same lesson using PhET’s online DC Circuit Simulator.

<http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc>* If you do not have any experience with circuits and are having trouble understanding the lesson, check with your science department teachers for assistance.
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***Electric Drill***

***Describe these terms:***

**Electricity** –

**Conductor** –

**Insulator** –

**LED** –

**Battery** –

**Circuit** –

***Electric Drill***

***Describe these terms:***

**Electricity** –

**Conductor** –

**Insulator** –

**LED** –

**Battery** –

**Circuit** –

Life in the Information Age revolves around electric circuits. These can be as large as the power grid that distributes the energy we use, or as small as microscopic circuits in our computing devices. Today you will learn about series and parallel circuits and create your own circuits using only this paper, your pencil, a 9V battery, and a Light Emitting Diode (LED).

1. **Create a series circuit!**

**Series Circuit** – only one possible route for electrons to flow through circuit

1. Use your pencil to Color in the lines below to make your Series Circuit:
2. Set the 9V battery upside down on the left side of the circuit
3. Hold the LED leads (metal prongs) to each side of the right circuit

*If the LED does not light:*

* Try reversing the polarity of the battery (rotate it 180 degrees). The LED will only light in one direction.
* Make sure the LED and battery are contacting the circuit branches
* Make sure your conductors (pencil lines) are drawn very dark!



LED

9V



1. Once your circuit lights up, erase a small section from your circuit
	1. You should see the bulb turn off. This is exactly what your light switch does!
2. **You just made a series circuit. Now, draw your own *parallel* circuit (from scratch)!**

**Parallel Circuit** – More than one path for electrons to flow (imagine a ladder with the outside leads supplying the power and the components between)

1. Follow the same steps as the Series Circuit above
2. Add at least two “branches” to your circuit with a LED on each

**Reflection:**

1. A common way to think about series and parallel circuits is to think of a string of Christmas lights. **Sometimes when a bulb burns out, many (or all) bulbs stop being lit too.** What kind of circuit is that based on your knowledge of series and parallel circuits? Explain your answer.

A string of Christmas lights that causes multiple lights to go dark when one burns out is a series circuit. Because an incandescent bulb causes an open cicuit when the filament burns out, there is no longer a path for electricity to flow through the other lights connected in series. If the lights were wired in parallel, the electricity could simply flow past the burnt out (open) branch of the circuit. See the image above and to the right.

1. If you were designing the lighting system for your classroom, which type of circuit would be better to use for all of the lights – series or parallel? Explain why.

Parallel would be better to use. There are many lights required to illuminate a classroom. When one bulb goes out, you don’t want the entire room to go dark. If they all went dark at the same time, it would also be very difficult to find the one that was burnt out.