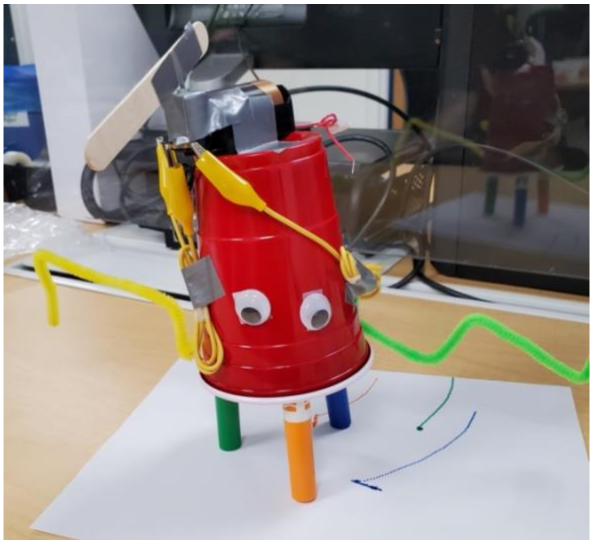
LESSON: Circuits (Grades 4-6)

+ OVERVIEW



In this design challenge, students will be tasked with improving an existing toy design called a Wigglebot. The Wigglebot can wiggle using a DC motor, a device that converts electrical energy into mechanical energy through rotation. Students will learn about electricity and circuitry before taking on the challenge of adding more features to this toy. The students will be presented with the following problem: “**Maria’s company currently sells Wigglebots, but has gotten feedback from her market research that they need to do more than just wiggle. She is looking to improve the design of this toy to include more features while keeping the same look.”** Students will put on their engineering hats to help Maria improve the design of her toy. Students will engage in a STEM challenge to design a Wigglebot that produces light and sound while still able to wiggle.

+ 2021 Science TEKS covered in this design challenge

Grade 4 TEKS: 4.1.B, 4.1.E, 4.1.G, 4.2.D, 4.8.B, 4.8.C

Grade 5 TEKS: 5.1.B, 5.1.E, 5.1.G, 5.2.D, 5.8.A, 5.8.B

+ Math TEKS covered in this design challenge

Grade 4 TEKS: 4.8.C

Grade 5 TEKS: 5.10.F

Grade 6 TEKS: 6.3.D

+ 2022 Technology Applications TEKS covered in this design challenge

Grade 4 TEKS: 4.3.A, 4.3.B

Grade 5 TEKS: 5.3.A, 5.3.B

Grade 6 TEKS: 6.1.C, 6.4.B, 6.4.C

+ The students will be able to:

- Identify conductors and insulators of electrical energy
- Demonstrate that the electrical energy in complete circuits can be transformed into motion, light, sound, or thermal energy
- Describe how energy is conserved through transfers and transformations
- Solve problems that deal with money using addition and subtraction
- Balance a simple budget
- Add, subtract, multiply, and divide integers fluently
- Demonstrate personal skills and behaviors, including problem solving and questioning, effective communication, following directions, mental agility, and metacognition
- Solve a problem using the engineering design process

+ Students will use the following STEM fluency skills:

- Communication
- Collaboration
- Creativity
- Critical Thinking
- Resilience
- Time/Resource Management
- Innovation
- Adaptability

+ Materials needed for this design challenge:

Item	Cost
Plastic Solo Cup	No cost
DC Motor	No cost
2xAA or 2xC Battery Pack Holder	No cost
2xAA or 2xC Batteries	No cost
Markers	$1 per marker (First 3 no cost)
LEDs	$5 per LED
Masking Tape	$5 per roll
Electrical Tape	$3 per roll
Chenille Sticks	$1 per stick
Googly Eyes	$1 per eye
Clothespins	$1 per pin
Alligator Clips (Wires)	$1 per clip
Scissors	$5 per pair

+ Materials needed by the facilitator:

> Projector and computer
> Slide deck for the lesson
> Internet access or pre-download simulation from PhET
> Copies of the scorecard for each group
> Timing device
> Energy stick
> Construction paper
> Alligator clip
> Rope or string (Optional)
> Pre-built wigglebot base
- Plastic solo cup
- DC motor
- 3 Markers
- Duct tape
- 2xC batteries w/ holder OR 2xAA batteries w/ holder

+ FACILITATION GUIDE

SECTION	PROCEDURE
INTRODUCTION	**Slide 1: Circuits** **Slide 2: Electricity** > Ask students if they know what electricity is. ▪ Explain that electricity is a form of energy resulting from charged particles. > Ask students if they know what an electrical current is. ▪ Explain that an electric current is a flow of charged particles—negative particles like to move toward positive areas. > Conduct a human circuit example using an energy stick. ▪ The teacher will present the energy stick to the class and hold one end of the stick in one hand. The teacher will then take their other hand and grab the other end of the stick. The energy stick will turn “on,” demonstrating that a circuit has been completed. The teacher will extend the demonstration by requesting a volunteer. The teacher and volunteer will each hold one end of the stick; it will be “off”. If the teacher and volunteer touch hands, the energy stick will turn “on”. The teacher will take an alligator clip in one hand and have the volunteer hold the other end. The teacher will hold the metal part of the alligator clip, but the volunteer will not. The teacher will ask the students, “Why is nothing happening?” The volunteer will then grab the metal part of the alligator clip. The energy stick will then turn “on”. • Optional: The teacher may take a rope or string and ask students, “What will happen now?” The volunteer will grab the other end of the rope/string, and the energy stick will stay “off”. > PhET simulation: Closed circuit example ▪ Have students take their tablets to their stations and open up the simulation. The teacher will also open a simulation to project onto the screen(s). The teacher should model for students how to pull down a battery and a light bulb. The teacher will ask the students how to turn on the light bulb. Based on the answers given, the students will complete their instructions to see if their answers are correct. Once the solution is successful, have students reset their simulation by hitting the reset button at the bottom right of the screen. In the simulation, place one battery and three light bulbs, and ask students to turn on all three bulbs. The teacher will monitor and check on student solutions. As students work on a solution, the

	teacher will set up an additional battery and three light bulbs and emphasize that there are two ways to solve this problem. Students are free to talk and work with one another at their stations to find a solution. • Students can turn the bulbs on through a series or parallel circuit. The teacher will demonstrate both solution types on the screen(s). The teacher will let students know that parallel circuits will be used for today's activity. • The teacher must confirm with students which circuit is parallel. (The one with the wires going from the battery to the light bulb for each light bulb). **Slide 3: Engineering Design 1** > Ask students the question: What is engineering? ▪ Explain to students that engineering is when engineers take what they know and apply it to solve problems by designing a product or process. ▪ For example, phones could only be used at home or in specific locations. Why is this a problem? (Needing to make a call outside the home). What solution did engineers design to fix that problem? (Cell phones). • *Teacher's Note: Any example can be used here, but focus on examples that students are familiar with.* **Slide 4: Engineering Design 2** > Ask students the question: What are some examples of engineering jobs? ▪ *Teacher's Note: If students have trouble giving examples, ask students who they think makes the things they use. Who makes refrigerators, cars, helmets, cell phones, and sneakers?* **Slides 5-7: STEM Careers** > Show students pictures related to careers connected to the challenge. > Mechanical Engineering ▪ Ask students what they see in the pictures. ▪ The people who work on cars, trucks, and machinery are called mechanical engineers. They design and build various solutions to problems involving mechanical parts or processes. There are many electronic components in cars now. Many of them use computer chips to regulate how the car performs. Mechanical engineers incorporate circuits into the design of motors and other car components to improve performance. > Electrical Engineering ▪ Ask students what they see in the pictures. ▪ The people who work with the electronic devices that we use every day are called electrical engineers. There are circuit

	chips inside every electronic device, and electrical engineers are the ones who design them. Electrical engineers think about how to integrate technology into society to solve problems. > Chemical Engineering ▪ Ask students what they see in the pictures. ▪ Explain that chemical engineers study materials and how they interact. They help create products that are safe, durable, and work the way people want them to. ▪ Explain to students that a chemical engineer working on the Wigglebot project might investigate materials that could make the toy more colorful, stronger, or able to glow. They would help choose safe materials for the toy's lights, sound components, decorations, and outer covering. **Slide 8: Try the Trade** > Electrician ▪ Ask students what they see in the pictures. ▪ Explain that electricians work with electrical systems that power lights, motors, sounds, and other devices. They make sure electricity flows safely from one part of a system to another. ▪ Explain to students that an electrician working on the Wigglebot project would help connect the battery, wires, motor, lights, and sound components so the toy can wiggle, light up, and make sounds. They would ensure that all electrical connections are safe and working properly. **Slide 9: Engineering Design 3** > Ask students the question: Who can be an engineer? ▪ Anyone! **Slide 10: Engineering Design Process** > Ask students if they think all engineers solve their problems in one try. Explain to students that it takes many tries to get something correct in engineering. In engineering, there is no such thing as a mistake, only opportunities to learn. It is okay to fail. Just find the mistake and correct it. In engineering, there is never one correct solution. There are always many solutions to a problem, and there are always improvements that can be made. The steps that engineers take to find these solutions are called the *engineering design process*. > Ask students to read the first big step (Identify). ▪ What does identify mean? (To point out or find). Engineers design solutions: what do they need to know first before they can find the answer? (The problem) ▪ How do people know when they have found the correct answer? In engineering, there are no correct answers, just better ones. Explain to students that there are expectations that

	engineers must meet, called *criteria*. For example, when engineering a football, what does a football need to do? (Bounce, look a certain way, have laces, have air inside, etc.). Those things are all called criteria. By comparing the design to the criteria, an engineer knows a solution will work. Is a child-sized football the same as an adult football? The criteria for both footballs include leather, white laces for the fingers, and shape. However, the two footballs would have different size criteria. The footballs are similar but differ in certain criteria. ▪ Once the criteria are understood for the design challenge, what could make it difficult for an engineer to design their solution? (Money, time, materials, etc.) Explain to students that these rules are called *constraints* or rules that engineers must follow. Engineers are given constraints they must follow when solving a problem. Think about football again. What are college and professional footballs made from? (Leather). What if, instead, the rule (or constraint) was not to use leather? Could another type of football be made instead? Many of the footballs for sale are made of rubber because the engineer had different constraints. > Ask students to read the next step (Imagine). ▪ Ask students what imagine, or imagination, means. Are these things real or tangible? They may not be real, but they help us imagine what things could be. In this step, see what materials are available, then brainstorm possible ideas and solutions to the problems. > Explain to students that there are no right answers in engineering. Start with as many ideas as possible. > Ask students to read the next step (Plan). ▪ The third big step of the engineering design process is to plan out the idea. Make sure that what is designed can be repeated. A plan will help an engineer identify where mistakes happen so they can be fixed. ▪ When planning, begin with the brainstorming phase. Each team member will contribute their ideas, and then the team will combine the different ideas! ▪ Once ideas are combined into a single group idea, determine what materials will be used for the solution and make sure the design meets the criteria and constraints of the project. > Ask students to read the next step (Create). ▪ The fourth step is to create! Since this is the very first creation, it is called a *prototype*. A prototype is a first or preliminary model of something from which other forms are developed or copied. A prototype is created to test the engineer's idea or concept. Engineers ask themselves, "Did the idea work the way

	we wanted it to?" After testing the idea, the engineer will make improvements to the prototype. > Ask students to read the last step (Improve). ▪ Finally, the last step is to improve. How does an engineer know if the prototype did well on the test? It must meet certain expectations and follow some rules. But how do engineers determine how well it met expectations and followed the rules? In school, how do you know if you mastered something? (Grades). The prototypes made today will be scored using a scorecard or rubric. By looking at the score, each team will determine if the design could be better. If improvements are needed, the team will revisit the plan and decide how to improve the score. Remember, there are no correct answers in engineering, just better solutions.
IDENTIFY	**Slide 11-12: Identify** – Problem > Have students read the bolded section. ▪ Ask students to *identify the problem*. > Explain to students that they will put on their engineering hats to design a toy. **Slide 13: Identify** – Criteria (Desired Outcomes) > Ask students what criteria or desired outcomes mean. ▪ Explain to students that criteria are what engineers use to determine if they have successfully solved the engineering problem. > Ask students what determines if the solution is successful today. ▪ A successful Wigglebot design should include the following: • Ability to light up • Ability to wiggle • Not fall over when powered Bonus points will be awarded for including a technical drawing. • Explain to students that a technical drawing outlines the elements of the electrical design. It is similar to the PhET simulation, where there was a battery with wires connecting to the lightbulb. Students can create a drawing showing how the battery connects to the different parts of the Wigglebot, the direction of the electric current (positive or negative), and labeling what type of energy transformation occurred.

	Slide 14-15: Identify – Constraints (Limitations) > Explain to students that constraints are rules the engineers must follow. > Explain the constraints for this engineering design activity: ▪ Time Limit: Students will have 30 minutes to build the improved Wigglebot. ▪ Materials: Students will only be able to use the materials available. ▪ Budget: Students will have $20.00 to complete this challenge • *Teacher Note: Fake money can be given to each group to represent their budget. Students would then go to the supply table and hand the teacher the money to "buy" their materials.* ▪ Collaboration: One design element from each team member must be used in the final design. Explain to students that a design element is taking one part of someone's idea and adding it to another. ▪ Redesign: Each team can test their prototype as many times as needed during the 30-minute design phase. Remind students what a prototype is. It is the first creation of our design. • *Teacher's Note: When a team is ready to test their design, they should raise their hand, and the teacher should assist the team with their score. If the team receives a low score on any part of the design, the team should redesign if they still have time.*
IMAGINE	**Slide 16: Imagine** – Explore Materials > The teacher will show students the base of the Wigglebot. Students will use this base model to improve the design of the Wigglebot and help Maria. The base model will turn on and vibrate, with no visual design. The base model will also demonstrate how a clothespin or an alligator clip allows the Wigglebot to "wiggle". Students will have their base model of the cup, legs, and battery holder pre-built. They will have to determine where they want to place their motor and LED and how to complete their circuit. Circuits will be completed using alligator clips. ▪ *Teacher's Note: Differentiation in this activity will be based on how much of the Wigglebot is pre-built. The baseline is having the Wigglebot fully built, with students only needing to add LEDs to the design. Higher-achieving students may start with just the base of the Wigglebot, the cup, and the markers (see picture).* 

	> Present the materials available to students. 3mm LEDs come in red, orange, and infrared (which can only be seen on a digital camera screen). When alligator clips are presented, explain to students that there is a wire running through them, and show how connecting the alligator clips from the battery to the motor turns it on, and how connecting the alligator clips from the battery to the LED turns it on. Let students know red is positive and must go to the long leg of the LED, and black is negative and must go to the short leg. ▪ *Teacher's Note: Students should check their connections and then unhook the alligator clips during testing for safety precautions. The motors can get hot and burn out if connected for the entire time.* **Slide 17: Imagine** – Brainstorm > Give students one minute to individually design and draw a plan of what they think their Wigglebot should look like. Emphasize that students should not talk during this minute or share ideas. Remind students that their ideas will be used as design elements for the final design. > After a minute, give students five minutes to present and share their ideas with their group. Let students know that, when sharing, they should focus on the key aspects of their idea they like and want to use as design elements in the final design. ▪ *Teacher's Note: If students are struggling with an idea for their design, provide ideas without giving the solution. For example, "This is a design that I tried earlier, but it failed. What could I do to improve it?" Emphasize that the design failed to reinforce that it is okay to fail, and to let students know they cannot copy the design and expect success*
PLAN	**Slide 18: Plan** – Gather Materials > Hand out the scorecard that will be used during the design challenge. Review the testing criteria with the class and answer questions. The testing criteria will inform their design decisions. > Have students collaborate to come up with a final design. Let students know they must include at least one element from each team member for their final design. > Review the design criteria: ▪ A successful Wigglebot design should include the following: • Ability to light up • Ability to wiggle • Not fall over when powered Bonus points will be awarded for including a technical drawing. ▪ *Teacher's Note: Students will not be expected to rank themselves or calculate their scores, but the teacher should explain how they will earn points. The testing criteria will inform their design decisions.*

	> Students will need to select the materials to be used for the design and develop a budget for the project. Students will have $20 to “purchase” materials for their build at the classroom supply table. The prices used in this challenge can be found in the materials list. Students will raise their hands when they are ready to purchase materials. The teacher will make sure the appropriate amount of money is spent to purchase each material, but will not guide students on following their budget. Students can go over budget if they want to, but remind them that they will lose points on their scorecard. **Slide 19: Plan** – Team Member Responsibilities (Career Role-Play) > Assign each student a career role within their team. As students complete the challenge, they should make decisions and contribute from the perspective of their assigned career. This activity models how STEM and skilled trade professionals collaborate in the real world to design, build, test, and improve their prototype. ▪ <u>Chemical Engineer</u>: Tests that materials are working as planned, keeps track of the building materials, and manages the budget ▪ <u>Electrical Engineer:</u> Draws the team's plan for the Wigglebot, ensures it follows the plan, and is safe for use ▪ <u>Electrician</u>: Builds the Wigglebot with assistance from the group ▪ <u>Materials Engineer</u>: Tests the Wigglebot and works with the team to make improvements, if needed
CREATE	**Slide 20: Create** – Design Your Toy > Let students know to have fun, be creative with their designs, and work together. > Remind students that being an engineer is not about getting the solution on the first try. There is no right answer, just better solutions. **Slide 21: Identify** – Criteria > Display the reminder slide for students to look at while working. **Slide 22-23: Create** – Test > When students are ready to test, they will raise their hands and bring their Wigglebot to the testing station. The teacher will ask the students to remove the marker caps and test the Wigglebot on top of a sheet of construction paper. If the Wigglebot fails the stability test with the marker caps off, students may retest with the marker caps on but will receive a lower score in that category. > Students will calculate their scores when testing in front of the teacher. The teacher will go through each category on the scorecard with the students. The students will mark their scores and calculate the total.

	> The teacher will recap the point total with the students and how many points the team received for each category to make sure it matches what the students recorded.
IMPROVE	**Slide 24: Improve** – Redesign: Discussion > Students will reflect on their scores and discuss: ▪ What worked? • *Teacher's Note: Focus on the Wigglebot's behavior. How did the Wigglebot "wiggle"? How did the Wigglebot light up?* ▪ What did not work? • *Teacher's Note: Focus on the Wigglebot's behavior. Which of the criteria did the Wigglebot not meet? Why did the Wigglebot not behave as expected?* ▪ What do you want to improve? • *Teacher's Note: Focus on the Wigglebot's behavior and the engineering design process. What materials or design elements felt successful or unsuccessful? Ask students how they would design their Wigglebots differently if they had no constraints. Ask students if working together was difficult. Learning to work together is very important, and it is easier to find a solution with many ideas rather than just one idea.*