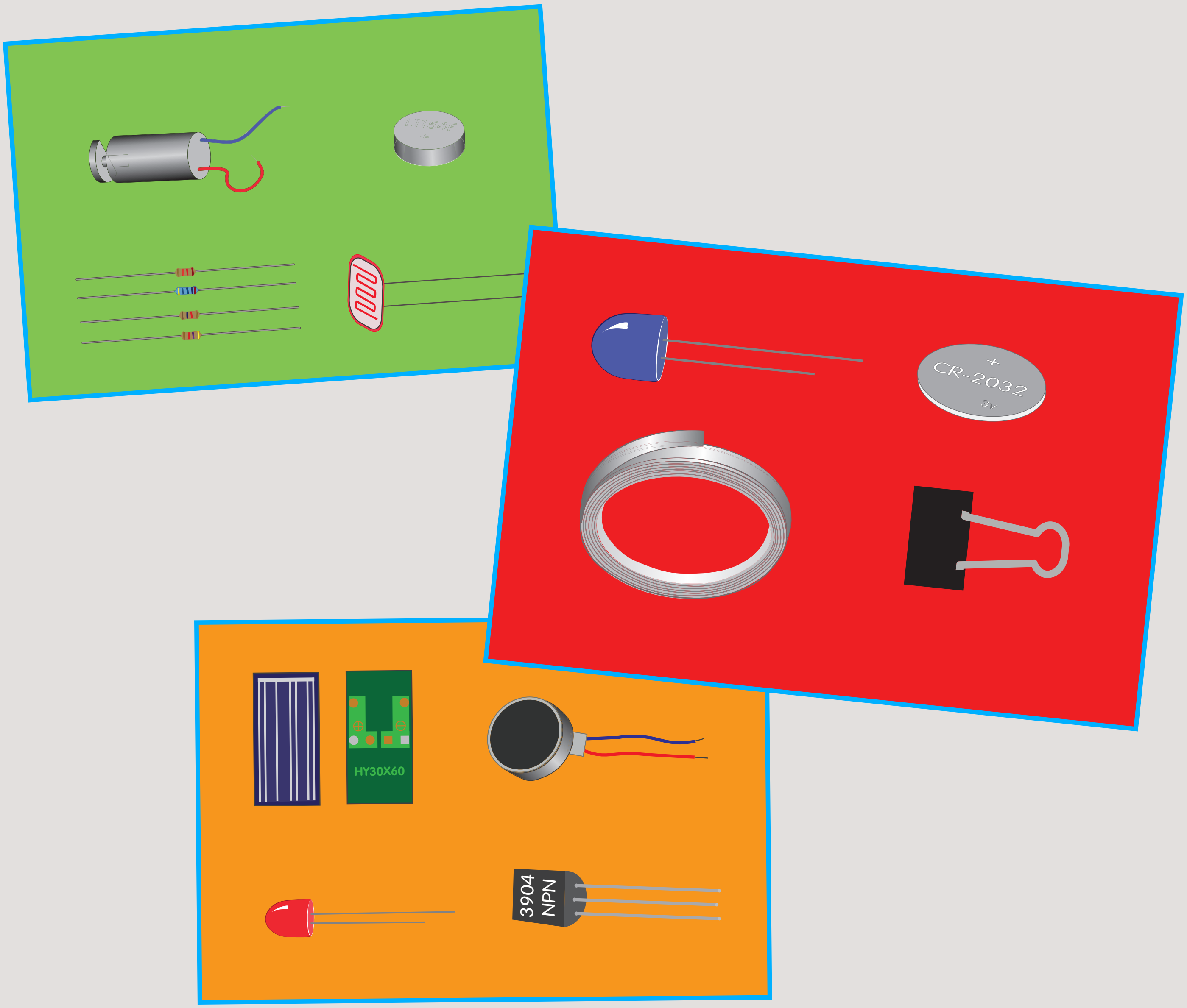
Distance Learning Kit

Lesson Plans for Student Workbook



BROWN DOG Gadgets

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Distance Learning Kit

Video Content

We've created a series of videos which cover some of the basics of circuitry and electronics. You can view the playlist (or any individual video) by using the links below.

Full Playlist: https://www.youtube.com/playlist?list=PL7UlsfFe3ZU2CG0PVDg6Bx9XNmz1Uf8N1

Buttons are used in electronics to close (turn on) a circuit when the button is being pressed.
https://youtu.be/AvwesPxOC10
Runtime: 3:38

Switches are used in electronics to change a circuit path to be open (off) or closed (on).
https://youtu.be/TtRn40pcla8
Runtime: 4:06

Motors are used in electronics to make things move. (Magetism is the secret ingredient!)
https://youtu.be/yUJ90_3mJS8
Runtime: 6:09

Batteries are used to power to a circuit. They can light up an LED, or make a motor move.
https://youtu.be/psuyYp_d6Zs
Runtime: 3:48

Potentiometers provide a variable (analog) input signal to a circuit. Rather than just the "on/off" of a switch, a potentiometer has a range of values like a volume control on a stereo.
https://youtu.be/owOvwVcznRM
Runtime: 4:30

LEDs (Light Emitting Diodes) are components that light up when electrical current flows through them in a certain direction.
https://youtu.be/yxMJO8Gdmh4
Runtime: 5:25

Distance Learning Kit

Lesson Plans for Student Workbook

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Preface

Welcome to the engaging world of paper circuits! Use this e-book and the contents of your group's Basic Brown Dog Gadgets Distance Learning Kit OR Deluxe Brown Dog Gadgets Distance Learning Kits to guide your students through a week-long investigation of circuitry basics.

Basic vs. Deluxe Kits

This ebook contains parts descriptions and activities for BOTH Basic and Deluxe Distance Learning Kits. If you and your students are working with the Basic Kit, simply focus on the first page of the parts description and Days 1-5 of the curriculum. If you are working with the Deluxe Kit, start in the same way and continue with remaining days of curriculum/parts descriptions.

Documents

Each lesson included in this eBook features lesson plans intended for teacher reference/use as well as accompanying student documents. Student documents are intended for you, the educator, to send to your individual students. These student documents include student-specific circuit templates, diagrams, data sheets and worksheets to help your students complete each activity from a distance with ease while allowing you to monitor their progress and comprehension. In general, Circuit Diagrams and Student Worksheets are intended to be one-sided when printed unless otherwise noted on Day 10.

Within Teacher Docs

Content within the teacher document for each lesson is separated into categories for ease of access to background information and actual student activities. Look for the bold, colored headers to see what is **FOR YOU** and what are **ACTIVITIES FOR YOU TO FACILITATE** at a glance.

Sequence

Although each lesson is set up to be taught **sequentially** with foundational concepts presented first and more complex ones that follow, the activities **ARE** organized within that planned sequence by general topic and therefore **CAN BE** accessed and taught in the order that is most appropriate for your particular group's existing skill/understanding levels.

Day 1 Topic:
Basic Understandings and Characteristics of Electricity
Day 1 Activities:
Battery Examination, Conductivity Tester assembly/use for data gathering

Day 2 Topic:
Circuitry Basics
Day 2 Activities:
Component Categorization, One LED circuit assembly

Day 3 Topic:
Describing and Controlling Circuit State with Switches
Day 3 Activities:
Drawing Exercise, Binder Clip Switch Assembly, Lever Switch Assembly, Push Button Switch Assembly

Day 4 Topic:
Circuit arrangements that power more than one outcome component: Parallel and Series
Day 4 Activities:
Parallel and Series Circuit Assembly, Examination and Comparison

Day 5 Topic:
Advanced Switches, Application
Day 5 Activities:
Assembling the Two Position Switch, Four Position Switch and Rocketship Build

Sequence (continued)

Note: The following days of currciulum are supported by materials only included in the Deluxe Brown Dog Gadgets Distance Learning Kits.

Day 6 Topic:
Making Things Move: Motor use in circuits
Day 6 Activities: Motor Visualizer, BristleBot Build

Day 7 Topic:
Resistance is not futile; Resistor use in circuitry
Day 7 Activities:
Resistor Effects on LEDs, Dark Detecting Circuit

Day 8 Topic:
Transistor use in Circuitry
Day 8 Activities:
Touch-Activated Switch, Moisture Sensing Circuit

Day 9 Topic:
Go Solar! Using Solar panels as a voltage source
Day 9 Activities:
Single LED Solar circuit, Solar Bug Build

Day 10 Topic:
Circuit Outcomes and Material Properties
Day 10 Activities:
Edge-Lit LED Name Badge

CR-2032 Batteries

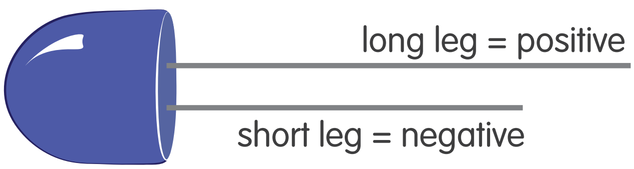
coin cell

Voltage Source (where electricity will come from and go to in your circuits).

Dimpled (Negative) side must always lead to short (negative) leg of your LED while long positive legs of LEDS must lead back to the positive side (pictured).

Found in: Basic **And** Deluxe Distance Learning Kits

10mm Jumbo LED

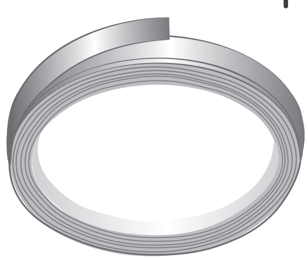


An outcome component that lights up when connected to battery correctly.

Short (negative) leg must connect to dimpled (negative) side of battery. Long (positive) leg must lead back to the opposite side of battery

Found in: Basic **And** Deluxe Distance Learning Kits

1/4" Maker Tape™

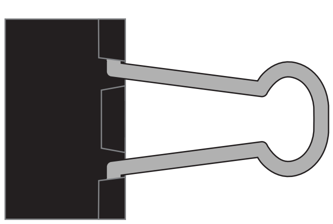


Makes conductive pathways!

This unique tape allows electricity to travel through it. You will be creating pathways with it that lead from the dimpled negative side of your battery to other components (LEDs, and switches) and then back to the positive side of the battery.

Found in: Basic **And** Deluxe Distance Learning Kits

Metal Binder Clip



Make a switch or hold things in contact.

This common office supply has several properties that make it useful in creating a variety of switches. It can hold things in contact with one another and has metal parts that can flip side to side to span a distance.

Found in: Basic **And** Deluxe Distance Learning Kits

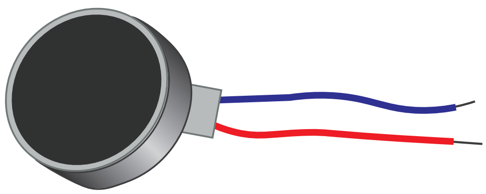
NPN Transistor

Used often as a simple electronic switch or amplifier.

For use in your moisture detecting and touch activated circuits. Negative path will need to connect to emitter while collector leads back to the Positive path.

Only Found in: Deluxe Distance Learning Kits

Self-Sticking Motor

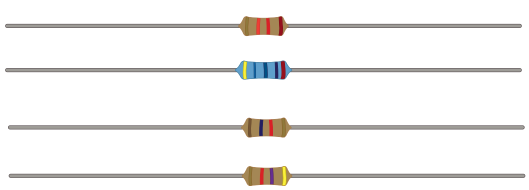


An outcome component; Vibrates/Moves what it's stuck to!

A small motor with a peel and stick back. Used specifically with Solar Bug and Paper Crafts in Motion Lesson. Wires do not have to be oriented any special way within pathways in order to work.

Only Found in: Deluxe Distance Learning Kits

Resistor Pack

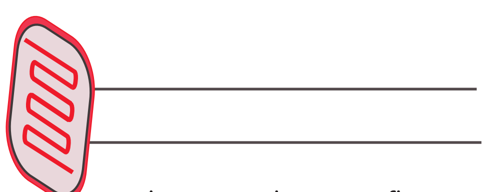


Each constricts the flow of electricity a certain amount.

Small components that can be wired in series with LEDs or motor. Wires do not have to be oriented any special way within pathways. Will cause LEDs to be dimmer and motors to spin more slowly.

Only Found in: Deluxe Distance Learning Kits

Photoresistor (LDR)



Changes electricity flow based on light conditions.

Similar to resistors that each have their own SINGLE value though LDRs can produce a RANGE of values depending on the light condition present. Wires do not have to be oriented any special way within pathways.

Only Found in: Deluxe Distance Learning Kits

L1154F Battery

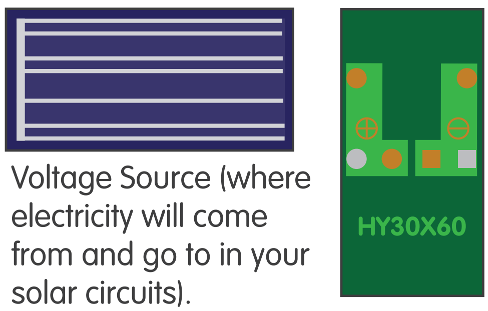
button cell

Voltage Source (where electricity will come from and go to in your circuits).

Small voltage source included to power Bristlebot project motor but can also reliably power up an LED. Dimpled side is negative (-) while smooth side with writing is positive (+).

Only Found in: Deluxe Distance Learning Kits

6v Solar Panel

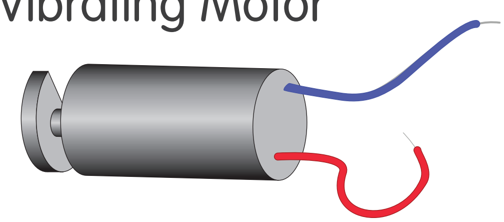


Voltage Source (where electricity will come from and go to in your solar circuits).

Voltage source used for Solar Bug Project and Single LED Solar Circuit. All components must be connected to silver square (-) and silver circle (+). Must be in direct sunlight in order to produce electricity.

Only Found in: Deluxe Distance Learning Kits

Vibrating Motor

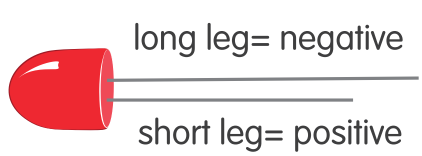


An outcome component that Vibrates/ Moves what it's stuck to with foam tape!

A small motor with an uneven weight on its spindle. Used specifically with Bristlebot project. Wires do not have to be oriented any special way in order to work.

Only Found in: Deluxe Distance Learning Kits

Red Blinking LED



An outcome component that blinks on and off by itself when connected to battery correctly.

Short (negative) leg must connect to dimpled (negative) side of battery. Long (positive) leg must lead back to the opposite (positive) side of battery.

Only Found in: Deluxe Distance Learning Kits

Circuitry with Basic & Deluxe Distance Learning Kit: Day 1

Content Area: Engineering/Science/Circuitry

Topic: Where can we find useable electricity in our kits and what are some of its characteristics?

Context: In today's lesson, you and your students will identify the source of electricity that will be used in subsequent lessons/activities. They will understand its role in powering up systems that use electricity and whether or not the electricity it supplies can travel freely through all materials.

Materials: Several sheets of paper, 1x Jumbo LED, CR2032 battery, scissors, printable worksheets/template, writing utensils, Maker Tape

Student Activity: Component Scavenger Hunt

Ask your students to think of things that use electricity. Where does the electricity come from that is used to power those items? A wall outlet? A battery? Afterward, ask your students to gather the materials listed above and, select/show the one item that they think has useable electricity stored in it. Confirm that everybody has selected and is now showing the small coin-cell battery to their webcams. Students should also take out and write down their observations and thoughts on the accompanying worksheet "Where can we find useable electricity & What are its characteristics?" Ask students to examine both sides of this battery and note that one side is marked with the (+) sign. This is the positive side of the battery. Ask students to guess how we refer to or describe the OPPOSITE side of the battery. That's correct: it's the negative side of the battery. Ask students to turn their battery back to the positive side and find the small "3v" indicated on the lower portion of that side. This is a measure of how much electricity will be supplied by this battery. The "v" is an abbreviation for a unit of measurement called "volts" and is a description of how MUCH electricity is supplied by this battery that we can now call the "voltage source" when it is used to power something up. Students should think of the two sides of this voltage source as the start and finish line of the systems that can be set up with items in their kits to make use of the electricity stored in their battery. When the two sides are not connected at all OR connected by something electricity cannot travel through, electricity remains stored in the battery. If the two sides are connected by something electricity can travel through, electricity will leave the battery from the negative side, travel through what is connecting the two sides and arrive at the positive side of the battery. The question remains: can electricity travel through ANYTHING??? The next activity and first project build will help them answer this very basic and important question.

Student Brainstorm: Ask your students if they have ever unplugged an electronic device from a wall outlet and lived to tell the tale (sarcastic gasp!). If they haven't already, ask them to do so right now **while noting two or three things as they are doing it**:

• There are 120v of electricity coming from the wall outlet power source; that's nearly 40 times what is coming from the little coin cell battery they will be using yet they didn't feel it shocking them!!!!

• The material that their hand is in contact with is likely plastic or rubber; while the center of the cord is metal wire (like the metal prongs that plug into the wall and connect to the power source hidden in the wall).

• The electricity was traveling from the outlet, through the center of the cord to whatever device it was powering on but NOT into whoever was grabbing the cord to remove the plug from the power source.

Ask your students to brainstorm what this simple, everyday experience tells us about electricity's relationship with different materials by using their worksheet to record and guide their thoughts. Would it be safe to do this same everyday activity if there was no plastic/rubber outside and the wire center of the cord was what they grabbed onto? NO! **Specifically, ask them to tell you:**

A) Is there evidence that, through plugging and unplugging an electronic device, electricity can travel? (yes...it WAS "in the wall" but when connected, allows the device to turn on. Thus, it had to be TRAVELING through the cord)

B) Is there evidence that electricity travels easily through all materials? (No. We know it traveled through the middle material because the device turns on when connected but we would be shocked if it could travel through the plastic/rubber that we physically came in contact with to plug/unplug it)

Educator Background: Conductors and Insulators

The world we are able to sense around us is relatively large. This STUFF that we see and feel daily is made up of smaller and smaller pieces and "basic ingredients" arranged differently to produce the differences we can sense on the big scale. This not only affects the way materials behave but also how they behave in relation to other things.

For this reason, electricity relates differently to different materials in a variety of ways.One major basic difference is whether or not it travels easily across the teeny tiny substructures that make a chunk of stuff what it is. **Describe the vocabulary term Conductor as a material that DOES allow electricity to travel through it and Insulator as a material that electricity will not travel through. In the next activity, your students will assemble something that allows them to tell if a given material is a Conductor or an Insulator.**

Student Activity: Conductivity Detector Assembly

Have your students independently follow the steps on the printable template "Conductivity Detector" to complete this device or lead them through its assembly directly. In either case, draw attention to the direction that the battery needs to be facing (positive side UP) and the orientation of the long and short legs of the LED. If the orientation of these parts is incorrect, the device won't work. What your students are creating today is a simple, one-LED light circuit with a planned gap within the pathway. Students do not need to understand this as a circuit yet and are only using this device to learn more about what electricity can and cannot flow through.

Student Activity: Device Examination.

Remind students that in order for the electricity stored in the battery to travel, the two sides of the voltage source need to be connected by material electricity can travel through. Explain that the silver Maker Tape included in their kits is similar to the material on the inside of the wire and will allow electricity to travel through it. With their device assembled, instruct your students to find the tape path that touches the underside of the battery and try to follow that path with their fingers all the way back to the top side of the battery. Are there any gaps in that path? Students should note that the path leading from the underside of the battery ends dangling at the edge of their paper. There is a paper gap next to it and then another separate path of that Maker Tape dangling off the edge; next-to-but-not touching the first path. If they follow THIS second path with their finger, students will find that it terminates atop the battery's positive side. In other words, your students should see that there IS a path from one side of the battery to the other but it is INCOMPLETE.
Inform students that they will use the LED being lit as proof that electricity IS flowing from one side of the battery to the other and when electricity is not, the LED will be off.
On their worksheet, ask students to observe and record which materials are between the gap in the path: (paper and/or air are acceptable answers). Ask students to observe/record what is happening at the LED when paper and air make up the gap in the path. The LED will be off and is evidence that electricity cannot flow through paper

OR air very easily. Now, ask students to touch the two dangly ends of maker tape together to complete the path and record their observation on their worksheet.
The LED should turn on and serve as evidence that electricity will flow through the entire device when that path is completed with materials that allow electricity to flow through it (Maker Tape). You should make sure everyone can demonstrate this LED is on when connected at these points before moving on. If anyone's device does NOT light up, ask only those students to double-check that their battery has the positive side UP and that the long and short LED legs are oriented EXACTLY the way they are shown on the diagram. If they need to pull their LED off and flip it they should simply lay the legs in position over the old path and cut/stick a small piece of Maker Tape on top (sandwiching the LED legs between).

Student Activity: Testing and Categorizing materials as Conductors or Insulators

Ask students to put away their first worksheet and take out their Conductor/Insulator data sheet. In this activity, students will independently test materials around their houses to start a list of common materials that DO allow the passage of electricity (conductors) and those that do not (insulators). At this point, introduce the terms Conductor and Insulator. The gap in the Maker Tape contact points that extend outward at its position that students will be touched to the ends of a sample material in an effort to tell whether or not electricity can easily flow through it. Students will use the LED being "on" as evidence that electricity is traveling through the sample whereas it being "off" as evidence of electricity not being able to travel through it. Try it on dogs, cats, golf balls, paper, wood, disinfectant wipes, tin foil, pillows, glass...ANYTHING (except a wall outlet)!

Circuitry with Basic & Deluxe Distance Learning Kit: Day 2

Content Area: Engineering/Science/Circuitry

Topic: What are systems that use flowing electricity and how can we assemble them with the components in our kits?

Context: Circuits are everywhere in our modern, built world and they all run on electricity. In today's activities, you and your students can put together two working light circuits of increasing complexity on paper with a CR2032 battery, 1-2 LEDs and conductive Maker Tape. Use accompanying documents to chart your children's understanding and have fun!

Materials: Several sheets of paper, 2 Jumbo LEDs, CR2032 battery, binder clip, scissors, printable worksheets, writing utensils, pan

Student Observation/Brainstorm Activity:

Demonstrate the following everyday experience for your students: Grab a pan from your kitchen and touch your fingers to the pan and bare metal of the pan. Ask your students to guess the temperature based on your reaction. Your non-reaction to touching the pan should hint at it being cool enough to touch. In other words, it has LOW thermal energy (a scientist's measure of HEAT energy). Ask your students to imagine putting this pan on a hot stove burner. Would the stove burner and the pan have the same amounts of thermal energy (heat) before they were put in contact with one another? No! Your students should note that the stove and pan would have DIFFERENT amounts of heat and the STOVE had more than the pan to begin with. Ask students to share with you what they think will happen to the temperature of the pan if put in contact with the stove. Students should be able to imagine that pan heating up. You'd be hard-pressed to find someone who would touch the pan knowing it had been on the stove for any amount of time and this should be sufficient evidence that there would be new thermal energy in the pan. This is thermal energy students verified wasn't there at the beginning of this exercise. Point out that the new thermal energy in the pan traveled from the stove INTO the pan. Ask your kids if that means the energy went from a place of higher concentration to lower or from where it was lower to where it was higher. It went from where it was higher (the stove) to where it was lower (the pan). Inform your students that this "high to low concentration" pattern of travel in energy happens all the time and is also the cause of electricity! Ask students to recall that their battery yesterday had a side from which electricity left from and a side where it went TO when connected. The reason for this predictable travel is related to a difference in concentration of a tiny particle called an "electron" on one side vs. the other. Ask students: If electrons follow the same high concentration to low concentration pattern that the heat did in the pan and stove example, which side of the battery has a higher concentration of the particle that is responsible for electricity?

Educator Background: Electricity Basics

Electricity:

- Is made of tiny parts (electrons) of the tiny parts (atoms) of the tiny parts (molecules and compound) that make up EVERYTHING around us.
- Involves a very specific, common but abnormal movement of those electrons.
- Involves electrons moving for a specific reason (higher concentrations near lower ones)

This curriculum will not go beyond this in terms of explaining what electricity IS but it's helpful for your students to know that the electrons that will be moving to power their LED circuits are in the battery; more concentrated on one side and less on the other which explains why yesterday's lesson described an "out" side to every battery and an "in" side as well. When a path of the right material (in our case Maker Tape) starting at one side of the battery is connected to the opposite side, the electrons will travel through that path from where they are more highly concentrated to where they are less. When we place components that NEED electricity to work within that path, the electrons will continue flowing through them and the rest of the path as long as everything is continuous from one side of the battery to the other. As a result, those components power up! We call these arrangements "circuits" and they are at the heart and soul of every electronic device in our home and beyond!

Student Activity: Circuit Part Categorization

Ask students to take out today's worksheet titled "What is a circuit and what do they need in order to work?" Inform them that the device they assembled and used yesterday to test conductivity is an arrangement called a circuit. Introduce the parts of a circuit and ask students to follow along on the student worksheet:

Circuits are a combination of:

- A voltage source (battery, generator, solar panel)
- Pathways from and back to the power source made of a material electricity can travel through (metals, graphite, etc.)
- Components connected TO that pathway that need electricity in order to work.

Ask your kids to examine the parts used on their conductivity detector from yesterday and them disassemble it while categorizing the components in one of the three areas on their sheet. This will reinforce the role each part plays in the circuit and allow you to verify understanding.

Student Activity: One LED circuit assembly

Have your students follow the steps on the printable template to complete the simple, one-LED circuit. Let your students know that they will basically be re-creating the same circuit that tested conductivity except without a gap. Folding the edge over and clipping it in place over the battery will bring the second end of the path in contact with the top of the battery while the other side is held in contact with the tape underneath it. It's true to say that there is still a gap in this circuit arrangement when the edge is not folded over and held in place by the binder clip. The clip makes the gap controlled by something other than the user actively holding two paths together.

Educator Background: LED Polarity

Sometimes it doesn't matter which way a component is oriented within a circuit. But, because of the way they operate, some parts DO need to be placed with a given path a certain way. We say these parts have a "polarity" or a "one side and its opposite". LEDs are polar parts so they won't work if placed within the circuit improperly; they ALSO have an "in" and an "out" just like your batteries. How can you tell which side is which? In many cases, + and – symbols are printed on components but sometimes there's something physically different about one side of the component. In LEDs, one of the legs is longer than the other. In life, sometimes we may talk about getting "the short end of the stick" which is basically a NEGATIVE thing that involves getting less than one deserves. The SHORTER leg on your LEDs is the negative side. The LONGER leg is the positive. Have your kids bend the shorter, negative leg out to the side and place it on the paper under the last little section of that first tape section because this is leading from the NEGATIVE side of the battery. The other leg should now be bent outward and held in place under part of the next path that leads back to the top of the battery as pictured. In order to turn the circuit ON, the last part of the last section of pathway must be pressed in contact with the top (positive) side of the battery. Want to turn it off? Simply peel the tape from the top of the battery.

Final Questions:

Circuits are all pathways that lead from and back to a power source with things doing work in between. When that pathway was incomplete (tape NOT in contact with the top of the battery) was the light ON or OFF? What about when that pathway WAS complete? What does that tell you about complete and incomplete circuits in relation to the components getting electricity to turn on or not?

Circuitry with Basic & Deluxe Distance Learning Kit: Day 3

Content Area: Engineering/Science/Circuitry

Topic: How do we describe circuits and control their intended outcomes with switches?

Context: It's one thing to be able to use a power source and designed pathway systems to power something up within those pathways, but it's an entirely new thing to be able to CONTROL that outcome. Think about it: what if all the things around you that are currently using electricity in circuits could only be on? Our ability to control what is happening at the outcome components in a circuit broadens their usefulness to us. One of the most basic ways to control a circuit outcome is to turn it on and off. Switches allow for us to do this without always plugging and unplugging or pulling a battery off. In this lesson, you and your child will learn what they do, how they do it and how to make a few types out of the basic materials in your Brown Dog Gadgets Sampler Pack and a few other common household items.

Materials: 1 Jumbo LED, CR2032 battery, Maker Tape, scissors, printable worksheets/templates, writing utensils, binder clip

Student Brainstorm:

We now know that we can make things turn on by creating a completed conductive pathway from and back to a voltage source. We also know that, by creating a gap in a conductive pathway, the circuit outcome is turned off. Introduce the vocabulary term "Open Circuit" as a circuit with an incomplete path from and back to the voltage source and "Closed Circuit" as a circuit with a complete path from and back to the voltage source. The gap in an open circuit can be created by connecting and disconnecting a part but is this convenient for a user? Is it safe? Ask your students to brainstorm the name of the thing that allows them to turn a light on and off at home. Your students should identify that it is a SWITCH that lets then do this. Now that they know a little bit about circuitry, your students can say that SWITCHES allow a circuit user to open and close pathways without unhooking anything. Have them use their Day 3 Student Sheet titled "Controlling circuit outcomes with switches" to first confirm their understanding of Open VS. Closed circuits and then go on a brief scavenger hunt in their home to record 3 electronic devices they found that allow for the user to turn it on/off as well as a description of the mechanism used as the switch. Was the switch a lever, a button…a slidey thing??? There are many kinds of switches.

Educator Background: Why/How switches work

When you and your students assembled and observed the previous lessons' circuits, there were moments when the LEDs were not lit up. What caused the dark moments? Here are three important scenarios that caused the LED(s) to NOT light up:

- when the corner was folded out of contact with the top of the battery
- when the two dangly ends of their conductivity testing device were not touching
- when the conductivity testing device was testing a sample between the dangly ends that was NOT conductive.

Here's the thing those situations all have in common: they ALL involve creating an incomplete path from one side of the power source back to the other, through the components. In other words, when circuit pathways have an opening or non-conductive gap in them, they are OFF. When circuit pathways have no gaps in them and are a CLOSED loop from and back to the battery, they are ON. Controlling this by digging into the guts of a circuit by hand can not only be unsafe but also inconvenient. Imagine having to hold to wires together for the entire duration of a movie being watched on a TV! Not only would that be unsafe with the 120 volts coming out the wall but who would want to do that anyway? Switches are simply, user-friendly components placed within gaps we create on purpose within the circuit. They allow a user to complete and break that planned gap in the pathway leading from and back to the power source easily from outside of the device where it's safe AND in ways that are useful to the way the circuit is designed to be used.

Student Activity: Switch 1 assembly/ Binder Clip

Remind your students of the basic rules they used to assemble previous circuits:
- A pathway of Maker Tape extending from UNDER the battery
- A pathway of Maker Tape leading back to the top of the battery
- Parts that need power within those pathways
- Those parts connected to the path in the correct way UNDER/IN CONTACT with the tape paths.

Have your students disassemble their 1 LED circuit from yesterday and inform them that today's first circuit will feature a different use of the binder clip. Yesterday the binder clip was used for its ability to provide constant tension on the path that needed to be held in contact with the top of the battery when the edge was folded over. Today students will use that same clip for its ability to swing something conductive on top of AND/OR away from a circuit gap. Instruct your students to follow the steps on the printable template “Paper Switches: Binder Clip” to complete the Binder Clip switch. When students all have this project with a switch completed, have them demonstrate it working and describe how the switch works on their worksheet.

Student Activity: Switch 2 assembly/ Lever Switch

Remind your children of the basic rules they used to assemble previous circuits:
• A pathway of Maker Tape extending from UNDER the battery
• A pathway of Maker Tape leading back to the top of the battery
• Parts that need power within those pathways
• Those parts connected to the path in the correct way UNDER/IN CONTACT with the tape paths.

First, instruct your students to disassemble the binder clip circuit by first attempting to remove half of the tape piece shown in the Lever Switch diagram. If they can successfully pull half of that tape piece up starting at the gap end of it and trim it at that point, they will only need to assemble and add the new switch to complete the Lever Switch circuit. If they pull too much of the paper up in the process, they should just use the Lever Switch template and start fresh. Have your kids follow the steps on the printable template "Paper Circuits at Home 3 Templates" to alter their binder clip circuit OR complete the Lever Switch circuit from scratch. When students all have this project with a switch completed, have them demonstrate it working and describe how the switch works on their worksheet.

Student Activity: Switch 3 assembly/ Push Button Switch

Remind your children of the basic rules they used to assemble previous circuits:
• A pathway of Maker Tape extending from UNDER the battery
• A pathway of Maker Tape leading back to the top of the battery
• Parts that need power within those pathways
• Those parts connected to the path in the correct way UNDER/IN CONTACT with the tape paths.

Have your kids follow the steps on the printable template “Paper Push Button” to complete the Push Button Switch. Once again, if your students can figure out how to carefully disassemble the previous circuit’s switch and add this new one in place, it may save them time. However, if their previous circuit becomes damaged in the process, they can just start fresh with the template.

Student Activity: Compare and Contrast

Compare and Contrast: Choose any pair or pairs of these switches you and your children created. How are they similar? How are they different from one another? Have your students use the attached Venn Diagram to help them compare and contrast two of the types of circuit arrangements and make a case for what they could use them to do!

Extension Idea:

Both the lever and the pushbutton switch assemblies are great switches to use in generating Morse Code messages for some fun silent communication! Have your students research what Morse Code is, when it was/is used for and brainstorm together about how they can use this or the pushbutton switch to send secret, silent messages with pulses of light they control by switch. Students can use the Morse Code information on the back of the Venn Diagram and one of these light circuits with a switch to send and then decode messages with a partner!

Circuitry with Basic & Deluxe Distance Learning Kit: Day 4

Content Area: Engineering/Science/Circuitry

Topic: Circuits with More Than One Component Series Circuits compared to Parallel Circuits

Context: Most circuits do way more than just light up one light. So, how does THAT work? There are a couple of different ways that components needing electricity can be arranged within a circuit to allow more than one thing to work at the same time. In today's lesson you and your students will explore the different arrangements that can be used to effectively supply power to more than one outcome in a circuit. Your students will not only assemble two different circuit types, but also run tests on those circuit types while logging observations so they can be compared/contrasted with one another on accompanying documents.

Materials: 2 Jumbo LEDs, Maker Tape, CR2032 battery, scissors, printable worksheets/templates, writing utensils

Student Brainstorm:

Ask your students to use their Day 4 worksheet titled "Circuits that create multiple outcomes" to brainstorm and describe scenarios when they've flipped a switch and multiple things have happened at once. Examples may include a) a single light switch turning on many overhead lights at once b) holiday lights in a string c) turning on a stereo and hearing not only sound but also seeing lights, d) a vacuum cleaner with a light and a motor, e) A desktop computer with a fan/button lights/monitor OR any other scenarios you can verify that they come up with. Once students have had a moment to write down some notes about the scenarios, encourage them to share with the group. After this discussion, instruct students to return focus to their worksheet to record their thoughts about two new scenarios about a river and some magnets. Their answers will later serve as reinforcement for understanding the two circuit arrangements they will assemble today.

Student Activity: Series Circuit Assembly

Inform your students that the first circuit arrangement they will assemble is called a series circuit and it will allow them to power up more than one LED outcome. The way components are arranged is comparable to the magnet joining idea explored in their worksheet. It is not the ONLY way these same number of parts can be powered up and it has both advantages and disadvantages. Students should remove the parts from yesterday's final circuit and use the diagram for "Series Circuit" to help them assemble. When all students have completed this project, have them demonstrate it working and then lead them through the test procedure below. The very first thing they should observe without testing anything is that, although the LEDs are both lit up, they are very dim. As they make observations during the testing procedure, students should record this observation and the rest of their findings on the Day 4 worksheet.

Student Circuit Testing Activity:

Have your students use the printable worksheet "Parallel vs Series" to help organize and record their observations of the following tests/observations:

1) **Your students should keep the circuits connected while testing.** They should observe that both lights work with one battery as the power source.

2) **Instruct your students to cut and set aside four small sections of Maker Tape for later use** and carefully (without pulling up the tape pathways) slip any single LED from beneath the circuit pathways and observe/record what happens to the remaining LED.

3) **Your students should now peel the backing off two of those small sections and use them to reconnect that LED in the spot it was located before** (remember to get the short leg to touch the lower battery tape path and the long one to the tape path that leads to the top of the battery). To do this, place the LED over the top of the tape in the correct position and then tape the legs so that the leg is sandwiched between the old lower tape path and the new smaller piece.

4) **Now, have your students remove the other LED and observe/record what happens** to the remaining one that should be newly reattached.

5) **After this, students should reattach the other LED with two remaining pieces of Maker Tape to get everything working again.**

Student Activity: Series Circuit Mapping

Ask your students to go to their series circuit and cover up any single LED with one hand. With the other hand, have them trace the tape path coming from under the battery all the way through the system until they get to the hand covering an LED. After that, they should do the same with the other LED. Covering the LEDs simulates a component breaking or becoming disconnected from the path. When arranged in series, circuit components are arranged in such a way that the complete path from and back to the power source always becomes incomplete no matter where or how many times a break or disconnect happens. If there's even one broken or disconnected part, the whole chain goes out. In addition, series circuits also take a bit more power to make it through all the parts on a single path. Parts arranged in parallel, by comparison, are all on their own separate path within the main one so the electricity hits each single part having first only gone through the main path and not all the other parts in a chain.

Student Activity: Parallel Circuit Variation 1 Assembly

Inform your students that the second circuit arrangement they will assemble is called a parallel circuit and it will also allow them to power up more than one LED outcome. The way components are arranged is comparable to the "river flow" idea explored in their worksheet. It also has both advantages and disadvantages. Students should remove the parts from their previous circuit and use the diagram for "Parallel Circuit" to help them assemble. When all students have completed this project, have them demonstrate it working and then lead them through the same test procedure you had for the series circuit. The very first thing they should observe without testing anything is that, not only are both of the LEDs lit up, they are both very bright. As they make observations during the testing procedure, students should record their findings on the Day 4 worksheet.

Student Circuit Testing Activity:

Have your students use the printable worksheet "Parallel vs Series" to help organize and record their observations of the following tests/observations:

1) **Your students should keep the circuits connected while testing.** They should observe that both lights work with one battery as the power source.

2) Now, have your students cut and set aside four small sections of Maker Tape for later use and carefully (without pulling up the tape pathways) slip any single LED from beneath the circuit pathways and observe/record what happens to the remaining LED.

3) Your students should now peel the backing off two of those small sections and use them to reconnect that LED in the spot it was located before (remember to get the short leg to touch the lower battery tape path and the long one to the tape path that leads to the top of the battery). To do this, place the LED over the top of the tape in the correct

position and then tape the legs so that the leg is sandwiched between the old lower tape path and the new smaller piece.

4) Now, have your students remove the other LED and observe/record what happens to the remaining one that should be newly reattached.

5) After this, kids should reattach the other LED with the remaining two new pieces of Maker Tape to get everything working again.

Student Activity: Parallel Circuit Mapping

Ask your students to go to their parallel circuit and cover up one LED with one hand. With the other hand, have them trace the tape path coming from under the battery all the way through the system until they get to the hand covering an LED. After that, they should do the same with the other LED. Covering the LEDs simulates a component breaking or becoming disconnected from the path and a gap being created. When arranged in parallel, circuit components are arranged in such a way that always allows at least one complete path from and back to the power source even if all the other paths and parts that branch off get broken. Your students should now disassemble this so the LEDs and battery are available for use in the final circuit arrangement.

Student Activity: Parallel Circuit Variation 2 Assembly

Inform your students that the third circuit arrangement they will assemble is a different way to connect multiple parts in parallel that is sometimes easier and more efficient to set up while having the same working outcome as the first. Students should remove the parts from their previous circuit and use the diagram for "Parallel Circuit Variation 2" to help them assemble.

Educator Background: Why parallel circuits behave as observed...

One way that engineers and professionals set up circuits that need to have multiple outcomes working at the same time is in an arrangement called a Parallel Circuit. To understand how parallel circuits work, remind your students of the river flowing toward a very tall island. When the river's current hits the island, the current divides into two branches; one that flows past the island on one side and another that flows past the island on the opposite side of the island. The water then rejoins on the downstream side of the island. Ask your kiddos what will happen if a dam is built to block the flow on one of those two sides. The water doesn't stop. It all flows to the side that has not been blocked. Parallel Circuits are set up so that the main pathway leading from the battery is never fully broken unless every component along it breaks. In their own circuit, any component could be removed and the other would still work because there was always still at least one fully connected way for the electricity to leave one side of the battery and travel through to the remaining side of the battery; powering up stuff along the way.

Student Activity: Compare and Contrast:

Which arrangement seems more useful? Have your students use the attached Venn Diagram to help them compare and contrast the two types of circuit arrangements and make a case for which one is better and when!

Circuitry with Basic & Deluxe Distance Learning Kit: Day 5

Content Area: Engineering/Science/Circuitry

Topic: Switches Beyond! Controlling Circuits with More Than One Component.

Context: Now that you and your students have seen the possibilities of both opening and closing a circuit with a control mechanism (switches) AND have also assembled and observed the two basic ways multiple outcome components can be powered up by a single voltage source, it's time to look at ways that those understandings can be unified. Today you and your class will be building on previous understandings to assemble two switches that each allow selective control of multiple LED outcomes.

Materials: 6 Jumbo LEDs, Maker Tape, 2 CR2032 batteries, scissors, printable worksheets/templates, writing utensils

Student Brainstorm Activity: Traffic Lights

Ask your students to consider a common red/yellow/green traffic light. This is an example of a single device with multiple outcomes that are all on the same circuit. Instruct students to use their worksheet titled "Switches for controlling multiple outcomes" to help record and organize their observations related to their past experience with this commonly encountered circuit. After giving students time to record their thoughts, ask them to share in a brief discussion that will provide some context for the two switch types they will be assembling shortly. Use this ultra quick experience reference to highlight that it is a single device with three outcomes that switch back and forth through a cycle where only ONE outcome is powered up at once. Now, it's true to say that actual traffic lights involve components within their circuits that are automated and controlled by computer code BUT how might we do such a thing with the circuitry that we already know about?

Student Activity: 2 Position Switch Assembly

Students should now disassemble their last circuit from yesterday. Afterward, ask them to examine the template/diagram for the 2 Position Switch and tell you which of the previous day's circuits it reminds them of. The circuit structure itself will resemble the first variation of the parallel circuit with two segments of Maker Tape missing. Ask students to indicate to you WHICH tape sections are missing and what they will be replaced with. Afterward, instruct your students to use the template to help them assemble the 2 Position Switch. When finished assembling it, make sure each student can demonstrate to you their working circuit.

Student Activity: Electicity Flow Mapping for the 2 Position Switch

Using their Day 5 worksheet, instruct your students to use the two diagrams depicting the switch for their circuit in each of its two positions to map out the way electricity flows through the circuit. They should also answer the questions about each scenario at the right hand side of each diagram to re-engage the vocabulary terms "open circuit" and "closed circuit" in their descriptions.

Student Activity: 4 Position Switch Assembly

Instruct your students to use the 4 Position Switch template to help them assemble the 4 Position Switch. When finished assembling it, make sure each student can demonstrate a working circuit.

Student Activity: Electicity Flow Mapping for the 4 Position Switch

Using their Day 5 worksheet, instruct your students to use the five diagrams depicting the switch for their circuit in different positions to map out the way electricity flows through the circuit. They should also describe the state of each circuit path within the circuit at the right hand side of each diagram for each switch position. This will also re-engage the vocabulary terms "open circuit" and "closed circuit" in their descriptions.

Student Activity: Compare and Contrast

Have your students use the Venn Diagram on their Day 5 worksheet to help them compare and contrast these two switches and imagine a use for each.

Educator Background: Multiple Position Switches

The two switches that you and your students assembled so far today rely on pressure contact with mutliple paths that cannot be complete, closed paths all at the same time. As the position of the switch mechanism (rotating tab in the 2 position switch and a finger for the 4 position switch) changes to apply pressure/conductive contact to a new portion of the circuit, outcome components turn on and off selectively.

Final Student Activity: Rocketship Project

With the time you and your class have remaining, your students should disassemble their 2 position switch circuit and use the components to build the rocketship project. This project involves a 2 LED parallel circuit within a fun context. The circuitry should feel very familiar to your students and should be considered independent work. If any students need to use it as a reference beyond the instructions on the template, there is a step-by-step guide that can be found online at:

https://browndoggadgets.dozuki.com/Guide/Rocket+Badge/191

Circuitry with the Deluxe Distance Learning Kit: Day 6

Content Area: Engineering/Science/Circuitry

Topic: Making things move: Basic motor use in circuitry.

Context: After having completed the lessons for days 1-5 of your Distance Learning Kit Curriculum, you and your students will understand the basics of circuitry using LEDs as the only outcome component. A quick inventory of the myriad types of circuit outcomes that are experienced daily should point to the reality that circuits can be set up to produce more than just lighting effects. Do they get placed within circuits in the same way? What are considerations that are specific to other components? If you are working with the Deluxe Version of the Distance Learning Kit, your students also have access to motors; an outcome component type that is at the heart and soul of many circuits that create and control motion. In today's lesson, your students will learn how to wire motors in circuits while testing and observing their characteristics.

Materials: Self-sticking motor, CR2032 Battery, Maker Tape, scissors, Printable Visualizer Discs template/Data Sheets, writing utensils, Masking or Invisible Tape, 10-20 Pennies

Educator Background: Forces and Motion
The second, third, and fourth student activities today use small paper discs with markings on them to help your students visualize the effects of a small handful of variable changes relative to how motors work and how the forces created by them can act on other objects to produce motion. For this reason, it's helpful for you to have a firm grasp of basic ideas related to force and motion. You can share this content with your students when you feel it is appropriate depending on how deeply you care to focus on the physics of force and motion. According to Newton's First Law of Motion, an object has two different states that it can be found in: at rest and in motion. Any object AT rest tends to remain at rest unless it is acted upon by a force greater than the sum of the forces keeping it in place. Speaking of forces, science calls any pull or push a force and one of the most elemental forces on our planet is the pulling force of gravity. Gravity is acting on literally anything on our planet with mass, pulling all mass toward the center of the Earth. This creates the maintained contact between objects of mass and the surfaces they are held in contact with. This contact pressure created by gravity acting on things with mass is referred to as the object's inertia and it's what needs to be overcome if the object is to go from the resting state to being in motion. So, what is motion? Motion is a word used to describe the act of changing what is called relative position: where something is located in space. When an object is located in one place and, by comparison, that changes through time, we say that the object was/is in motion. If its relative position is NOT changing, it is not in the state of motion...it is in the opposite state: rest. Today you and your students will be able to observe, through tinkering, some basic

realities of a common technology often used to create the forces necessary to move our built world: the electric motor.

Educator Background: Motors
There are many technologies that humans have developed to assist in providing the forces needed to make motion happen. Although you and your students will only be working with a small motor with an unevenly weighted mass on its rotating spindle, it's worth knowing a bit more about what is out there for engineers to choose from when selecting the components needed to complete a circuit project. We can categorize them in a number of ways; one of which being by the TYPE of motion they create. Some create circular, rotational motion and others create linear or back and forth motion. Another important distinction among these components is what powers them (which energy source gets converted into kinetic/mechanical energy). Some use electrical energy and others make use of compressed fluids like air, steam or incompressible liquids trapped in and released from closed cylinders. Some, like the engines in our cars, rely on controlled explosions from stored fuel to get moving!

Components that create rotational motion include:
- Motors
- Engines (both steam and internal combustion)
- Servos
- Rotary Actuators

Components that create linear motion include:
- Pneumatic or Hydraulic Pistons
- Pneumatic Muscles

Components that create motion and are powered by electricity include:
- Motors
- Servos

Components that create motion and are powered by pressurized fluids (gas or liquid) include:
- Pneumatic or Hydraulic Pistons
- Rotary Actuators
- Pneumatic Muscles
- Engines

Although the rotating spindle and weight attached to your motors aren't visible in the self-sticking motor, your first investigation will be centered on deciding whether motors create linear motion or rotational motion. Your second short investigation will take that understanding one step further by investigating, through simple adjustments in wiring, how polarity can alter that rotational motion's direction.

More about Motors
Motors, like all the components listed above, can be found in a variety of sizes and strengths.

Motors are not only trying to act upon an object's MASS but also the forces that are already acting on it such as the rubbing/pulling force of friction. Motors also all have a maximum twisting force that, in turn, limits how much mass they can effectively carry along with them & how much momentum they can give that mass. This maximum twisting force is called torque. Your third short investigation with these materials will involve testing the limits of what your students' tiny vibrating motors can actually move and how varying masses can impact the degree/rate of motion created in an object. They will also test and observe those differences while changing how much surface area/friction are in play.

Student Activity: Independent Simple Motor Circuit.

To start today's lesson, ask students to use what they know and have demonstrated in previous one LED circuit assemblies to wire up their self-sticking vibrating motor in place of the LED on a blank piece of paper. They will be doing this WITHOUT a diagram and should NOT peel and stick the motor to anything. Remind students that circuits are combinations of:

- **A voltage source (battery, generator, solar panel)**
- **Pathways from and back to the power source made of a material electricity can travel through (metals, graphite etc.)**
- **Components connected TO that pathway that need electricity in order to work.**

To assemble this circuit, one of the motor wires must be connected to a Maker Tape path leading FROM the underside (negative) of the battery while the remaining wire is connected to a Maker Tape path that leads back TO the top (positive) side of the battery. Assign half of your group to connect the blue wire to the negative path and the remaining half to connect the red one to that path instead. The primary objective here is for your students to re-engage their fledgling knowledge of general circuit setup WITHOUT a diagram while also showing that the same basic one LED setup can be used to power up different outcome components. The secondary objective here is to give your students an experience which allows them to generate a hypothesis about whether or not the motor is a polarized component. The outcome component students used last week (the LED) was polarized and would not even power up unless it was wired to the voltage source correctly. Although there IS a polar aspect to motors, the wires leading from them CAN be connected to a voltage source in any orientation and the motor will still work. Students should demonstrate a working motor circuit while also telling the rest of the group which color motor-wire they connected to the piece of Maker Tape leading from the underside of their battery. Without the motor body attached to their paper, your visual evidence of a working circuit will be the motor basically jumping around. Ask your students to recall what they knew about the LEDs from last week being a polarized component and, based on their current observation, use the first part of the student worksheet for day 6 to tell if they would categorize their electric motor in the same way. Many of your students will believe that the motor is not a polarized component because it turned on regardless of wire orientation though polarization is a bit more nuanced than "will it turn on in both orientations?" In the next activity/investigation, your group will further explore direction of motor motion and what polarity means to motor performance in circuits.

Student Activity: Rotational or Linear Motion

For the next simple investigation, the first question you and your students should seek to answer is whether the type of motion that is being produced by a motor is rotational or linear. To be able to see and verify that it is, in fact, a rotational motion, your students should cut out the 3.0" visualizer disc. Once outfitted with a vibrating motor/battery combo by sticking it to the center circle with Invisible (Scotch) Tape, students should be able to view the disc rotating when left on their desk at home. Even though

- the motor spindle is not directly connected to the paper
- the disc is being moved by motor vibrations

the disc will still move in that same rotational manner because of the vibrations' rotational origin. Your students should use any of the assembly instructions depicted on the visualizer print out while observing the rotation produced. They should use the Day 6 Student Worksheets to keep track of their data/observations.

Educator Background: Motors and Polarity

Just like our planet has a north pole and a south pole, other things also have a "one side and an opposite side". We often use the word polarity when discussing this concept in relation to electricity and magnetism. As this relates to components within electric circuits and the energy sources that power them up, it is true to say that:

- Every voltage source has a polarity; these poles are labeled as either + or –. The voltage source is where electricity with the potential to move originates. These poles serve as the start and end of a pathway system that includes components which use the travelling energy along the way. These systems of voltage, pathways and components are called circuits.
- Some but not all components in circuits ALSO have a polarity and their orientation when "patched into" the pathway system often changes the way they work (sometimes causing them to not work at all).
- Wire coating color, symbols & wire length are often used to indicate polarity.

Student Activity: How does motor polarity affect its performance?

Again, using their Day 6 student worksheets to focus investigation, instruct your students to use the arrows on their disc to verify the direction of the motion outcome of the motor circuit visualizer. Afterward, they should carefully remove the motor/battery combo and rewire it using the remaining wire orientation. Reattaching it to the disc, students should make and record their observations relative to direction of motion. They should see that polarity changes do not cause the motor to stop working... but they do cause the direction of rotational motion observed in investigation 1 to be reversed.

Student Activity: How Mass and Friction affect a motor's capacity to move.

Mass is a measure of how much stuff (matter) there is in something. Gravity pulls on that mass to produce what we call weight on a scale. The more mass there is in a given object to pull on top of the scale...the more weight.

In this investigation, your students will be testing the effects of increased mass of object on motion. Students may need to make a new tape loop (switching around the wires may have already made the connection less sticky and therefore less reliable) for each of the trials. Instruct your students to cut out the remainder of the visualizer discs. The discs will have slightly different weights and the motor battery combo will have a constant weight. Have your students predict which of these discs will rotate the fastest and then try each disc while paired with the battery/ motor combo, rating each for speed of rotation. In order to measure speed, you could have students let each trial run for 30 seconds while counting the number of completed rotations OR just qualitatively judge it via observation. Lastly, they can use more tape loops to stick an increasing number of pennies atop the motor in the center until the disc no longer rotates, effectively finding what might be the maximum mass that the motor's vibrations can act on. Before moving on to the next investigation, ask your students if they think there might be any other reasons for variation in how the same motor/same location moved each disc differently. Ask them to imagine two bikes rolling down the same hill one ridden by a man and the other by his clone. They are exactly the same weight... the hill and path down it are both exactly the same angle and texture... there is no wind and there are no brakes on the bikes. The only difference in the two bikes is the thickness of the tires. One has super thin, road racing tires and the other has tires that are twice as thick. Which will roll to a stop at the bottom of the hill first? The thick tired bike will! Why? Those wider tires have more of their surface area in contact with the ground and they produce more of a rubbing force called friction that must be overcome in order to move. Could this be responsible for some of the differences in how these discs of different mass move differently when being moved by the same force?

Student Activity: Penny location and pattern finding

In addition to mass, polarity, and friction, the way mass is distributed in an object will almost always affect how it moves when a force is applied. Allow your students some time to try out a variety of different penny placements using the 2.5" disc. Have them try at least 3 variations and record how they distributed the pennies and a line that describes the path that the disc traveled as a result (not the rotation of the disc...the path it travelled WHILE rotating). After students complete their three trials, challenge them to see if they can come up with ways to redistribute the weight via penny placement to create SPECIFIC, less "random" movements including:

- A straight line
- An arc to the right or left

Circuitry with the Deluxe Distance Learning Kit: Day 7

Content Area: Engineering/Science/Circuitry

Topic: Resistance is NOT futile; Resistor Use in circuitry.

Context: In day one of this curriculum, your students took a look at their battery and found that it has a polarity component as well as an "amount" (voltage) that can potentially be supplied by it. Wire some components up in relation to your battery wrong and some won't even work…wire a certain NUMBER of components in the wrong ARRANGEMENT and there might not be enough electricity available to power everything up. These are not, however, the only relevant characteristics of a voltage source that can impact the outcomes within a given circuit. Remember, anything that is in motion also has a speed or rate of travel…and electricity (electrons moving from atom to atom) is no different. Electricity coming from any source has a SPEED and, although that speed is extremely fast in comparison to most reference points your students have, the speed of electricity CAN vary from voltage source to voltage source. Outcome components themselves also have a certain electricity speed that they can "handle" and there ARE ways that the speed of the electricity coming from a voltage source can be altered to meet the needs of the components in a given circuit. Today's activities will explore the idea of resistance and resistors and what those concepts can mean in relation to circuit outcomes.

Materials: 1 red LED, CR2032 Battery, Maker Tape, scissors, 4 resistors, Photoresistor (LDR), Printable Resistor Tester template/Day 7 Worksheet, writing utensils

Educator Background: Amperage, resistance and resistors

Have you ever been on the road and driven over one of those long black cords draped across an intersection? It's there to measure and record how many vehicles have driven over it in a given chunk of time. Odds are, either a public utility or billboard company has it there so they can understand just how many cars are moving past that fixed point per hour or day. This kind of data can be very useful in roadway maintenance/billboard sales but, there is an analogous data point that is also important in the realm of electricity. A measurable characteristic of electricity that has not yet been introduced until today is "amperage" and it's what we use to describe the **amount** of electrons travelling from a voltage source. Every voltage source has an amperage rating and it is related to the quantity of electrons that will travel from it past a point within a circuit per second. So, if voltage is the pressure pushing electrons from a source, amperage is the amount of that pressure that can be expected to travel from it when connected to a circuit. This idea is also comparable to water leaving a water tower aimed at a turbine. Consider two identical water towers holding identical amounts of water with pipes leaving each of the towers at their bases.

One has a small diameter pipe letting the water out, while the other has a wide one. Both towers have the same pressure on the opening but which will let a greater volume of water out if gravity is the only force acting on it? A greater volume of water per unit of time will leave the tower out of the wide pipe opening than the other tower with the smaller diameter exit pipe. Now, let's imagine a turbine positioned below the each of the resulting streams. Both towers (batteries) have the same potential in them to create pressure at their respective opening. Yet, the setup that allows a greater VOLUME of water to travel will move the turbine more effectively. If we wanted to adjust the volume of water leaving at once in either scenario, we could widen or narrow a point along the exit pipe (or change the width of the highway in the cars analogy). The degree to which we constrict the flow in these analogies is comparable to something called resistence and it can be extremely useful in circuitry. The truth is, everything that electricity travels through adds a certain amount of resistance to a circuit but there are also specific components called resistors that function solely to constrict electron flow from a source on their way to outcome components. Some resistors look like little striped pills and constrict electron flow one specific amount. Others look different and have a whole range that they can constrict electron flow. These components can be useful in circuit design because each outcome component that may be involved in a circuit has a certain range of voltage and amperage that it functions best with. We rarely encounter a scenario where we can choose the "perfect" voltage/amperage source for what needs to be included in a particular circuit. Batteries come in a variety of standard voltages and amperages and wall outlet power is standardized too. Because of this, it is often the case that the "best" or "only available" amperage is used for a given circuit. Resistors are used to alter this characteristic of the electricity AFTER it leaves the source so that, by the time it reaches the outcome components, it is just right for their requirements.

Student Activity: Resistor Tester Circuit Assembly

Ask students to gather the materials listed for the day and use the Resistor Template to assemble what should look to your students like the same single LED circuit they had assembled on Day 3 of Week 1 except that there is no switch in the gap. Your group should already know that without something conductive to bridge that gap, the circuit is in an open state and will therefore not work to light up the LED. Their primary objective with this circuit setup is to first press (not stick) a piece of Maker Tape non-sticky side down over the gap in contact with paths "b and c". This will confirm for them that their circuit is set up correctly while also refreshing their memory on just how brightly the LED lights up. After this is done, they will use the same procedure for the 4 fixed resistance resistor. What your students should observe is that the LED brightness changes in comparison with each different resistor value tested. Instruct students to cycle through as many times as they need to while using their Day 7 Student Worksheet to guide and record their observations.

Student Activity: Photoresistor (LDR) Testing with the previous assembly.

After your class tests the fixed resistance resistors and answers the questions that reference their observations, you should be able to ask them to make an inference. If each resistor had a numeric value and each produced a different amount. Which resistor values made the dimmest light: High or Low? Which resistor values produced the brightest light? Your students should notice that the higher the value…the dimmer the light and the lower the value…the brighter the light. After you have confirmed their comprehension, inform them that they will now use that same circuit to test a whole new kind of resistor that does NOT have just one value. Ask students to find the Photoresistor and inform them that this type of resistor CHANGES its value depending upon the amount of light that is hitting it. Their task will be to use this part to bridge the gap, securing each wire atop paths "b,c" with 2 small pieces of Maker Tape. The reason we are actually securing this resistor in place is that there are no other resistors to swap in and out for comparison AND they might need some free hands to create the dark and light environment needed to see the variable effect this resistor has on the LED performance. Instruct your students to prepare two small pieces of Maker Tape and connect their LDR to the circuit. They should use their Day 7 Student Worksheet to guide and record their thoughts/observations about this part and how it functions. What should be observed is that, as the LDR is covered with their hand, the LED goes from bright to dark and when their hand is removed from the LDR, the LED goes from dark to bright. Students should use their worksheet and what they inferred about resistance values to lead them to the specifics of this new component's relationship with light. The less light…the more resistance and the dimmer the LED light. The more light….the lower the resistance and the brighter the LED light.

Educator background: Path of least resistance

Early in week one of this curriculum, you and your students had come to understand some of electricity's basic characteristics. We know that it has a measurable "quantity" when coming from a source (volts). We also know that it can't travel freely through everything. In addition, we have just learned that it also has a "speed" when coming from a source. We can use this idea of speed in combination with another reality about how electricity travels to create the final circuit for today: one that turns on in the night and turns off in the day with no switch. Oftentimes when electricity is travelling from a source, there is more than just one pathway it can take to get to where there is a lower concentration (why it's travelling from atom to atom through materials in the first place). Electricity may give the impression that it's a real hard worker but it's actually kind of lazy (or efficient if you're being generous). When given multiple viable paths to travel through en route from source (where it's more highly concentrated) to where it's deficient, understand that each of those paths may have a variety of resistance values. Electricity will always move through the path that offers it the LEAST amount of resistance. We call this the "path of least resistance" and, if we deliberately set up multiple pathways within a circuit with the right variety of resistance values, we can guide travelling electricity to and away from those paths under variable conditions to serve a purpose.

Student Activity: Dark Detecting Circuit v1

Ask your students to consider what has become a pretty common household item: the garden light that stays off during the day while turning on in the night without a switch. This very simple device can be created a number of different ways through circuitry and utilizes a photoresistor.

How does THIS device outcome differ from what your students just assembled to test the effects of an LDR on light output? Students should note that what they just assembled has the OPPOSITE effect that they are looking for: a light that gets dark when it's dark while getting brighter in the light. Instruct your students to use the Dark Detecting Circuit v1 template to guide their assembly of this new circuit. When complete and working, the LED will turn on when the LDR is covered (dark) and turn off when the LDR is exposed to light. Make sure your students are using the RED LED for this project. We haven't talked about the slight variation in voltage/resistance requirements for each COLOR of LED yet but know that there IS one. This circuit relies on resistance comparisons that are finely tuned to what's in the circuit/what is coming out of the battery. Because of this, other colors won't work reliably.

Educator background: How the dark detecting circuit works

In order to understand how this circuit setup works, it's first helpful to identify the two separate paths that have been set up within it. The first path leaves the underside of the battery (negative) and then goes to the LDR followed by a trip through a 4.7 ohm resistor before connecting back to the top (positive) side of the battery. This is essentially a "dummy path" without any outcome component present. It is only there to provide a "choice" for the electricity between it and the second path. The second path goes from the underside of the battery, through the red LED and then through that 4.7ohm resistor before connecting back to the top (positive) side of the battery. Collectively, everything located on each path has a certain amount of resistance, giving each path a "total resistance". The path with the LDR on it has a "total resistance" that can change because the resistance of the LDR can change. When it's dark, THAT path's resistance increases, while the path with the LED on it remains the same. By setting these two paths up within the same circuit we force the electricity to "decide" which path to go down, knowing that it will always play by the rules and take the path of least resistance when given the choice. When the LDR is in the light and has low resistance, ITS path has the least resistance and the electricity goes through IT and bypasses the LED path entirely. When the LDR is in the dark, its resistance increases and causes the total resistance of the LED path to be comparatively less. The electricity, therefore goes through IT and totally bypasses the higher resistance path before it.

Student Activity: Path Mapping for the Dark Detecting Circuit v1

As students test their circuit under both dark and light conditions, instruct them to use their worksheets to help map out the two paths that exist within it. Afterward, they should finish by answering the final two questions about their dark detector.

Circuitry with the Deluxe Distance Learning Kit: Day 8

Content Area: Engineering/Science/Circuitry

Topic: The Strange Magic of Transistors

Context: As circuits over time became more and more complicated, they required more and more switches as well as more power to certain portions to help them do all that they needed to do. Transistors are tiny circuit components that utilize some cleverly arranged materials to enable power to be amplified beyond them or for them to act as switches that electric current can turn on and off. Today's activities center on wiring two simple circuits that make use of transistors: one utilizing this component as a touch activated switch and another that is used to create a more efficient dark detecting circuit.

Materials: 1 red LED, 1 blue LED, CR2032 Battery, Maker Tape, scissors, 4 resistors, Photoresistor (LDR), 2N3904 NPN Transistor, Printable Circuit Templates/Day 8 Worksheet, writing utensils

Educator Background: NPN vs PNP transistors and how they work.

As mentioned briefly above, transistors can function as either switches or voltage amplifiers within circuits. Our focus today is to focus on their capacity to act as switches or gates within circuits. Instead of a hand or finger mechanically operating the switch, they open and close based on whether or not current is being applied to one of the three wires that come out of them. Although there are a few primary types of transistors, the most commonly encountered two are called NPN and PNP transistors. Regardless of type, these two types of transistors have a flat face and three wires. When looking at the flat side, the left wire is called the emitter. The middle wire is called the base. The wire on the right-hand side is called the collector. An NPN transistor turns on when electric current flows through the base. When it turns on, the path from collector to emitter becomes complete and allows electricity to flow through it. A PNP transistor's path from collector to emitter turns on when the opposite condition (no current hitting the base) is present. There is only an NPN transistor included in your kits. So, within the next circuit, the NPN rules apply.

Student Activity: Touch-Activated Transistor Switch

Instruct your students to gather a red LED, their 3904 NPN transistor and their battery. Using their parts sheet and the part itself as visual reference, ask students to examine their transistor and identify each of the three wires on it while looking at the flat face. The left-most wire is the emitter. The right-most wire is the collector and the middle wire is called the base. In this type of transistor, the path between the emitter and collector is inactive without current being applied to the base. When current hits the base, the pathway between the other two wires becomes active and allows current to flow through IT. After becoming acquainted with the physical aspects of this component, they should use the Touch Activated Transistor Switch template to complete the first circuit. Once assembled, the circuit will not show a working LED unless the operator's body is in contact with the base itself.

Educator background: How the Touch Activated Switch Circuit works

This circuit is a simple way to verify that, when current is applied to this transistor's base wire, the other path through it becomes active and allows current to flow through it. It starts with the understanding that there are two "voltage sources" needed for its operation: the battery (which is there to supply power to the LED when the emitter/collector path through the transistor is active) and the human touching the base (which is needed to activate the emitter/collector path). A small amount of measurable electric current is traveling through our bodies at all times and it can be transferred to the base wire by simply touching it. This activates the inactive transistor path and allows electricity from the battery to travel through the circuit, turning on the LED.

Student Activity: Dark Detecting Circuit v2 assembly

Instruct your students to find and use their printable Dark Detecting Circuit v2 template to help them assemble this circuit. There are many parts, connections and orientations of parts that matter in this circuit so encourage students to take their time while doing it. Students should take note that the transistor base is shown to be bent in the opposite direction as was used in their touch-activated switch circuit. They should bend the base wire carefully as the transistor wires CAN be a bit more brittle than the wires of other components. When the LDR is in a dark environment, the LED turns ON and when it is in a bright environment, the LED turns OFF. The question that is important here is: How is this different from v1 and what role does the transistor play in making it work that way. This circuit is a bit trickier to understand. So, a bit of explaining from you may be needed before your students can effectively use their Day 8 Student Worksheet.

Educator Background: How the Dark Detecting Circuit v2 works.

Careful examination of this circuit by you and your students will show there being three potential pathways that electricity can potentially travel through the circuit. The general idea behind how this circuit works begins with remembering: "path of least resistance", how LDRs work AND how NPN transistors work. Your students already know that electricity will always travel the path of least resistance and that LDRs change resistance when in different light conditions. The transistor here acts like a gate or switch that either allows current to travel from collector to emitter or prohibits it through those same points. As in their previous transistor circuit, when current hits the base wire the collector/emitter transistor path becomes active AND when current bypasses the base to travel the LDR path, that same collector/emitter transistor path becomes inactive. When the LDR is in a bright environment, its path is lower in resistance than the base and the current travels through IT, bypassing the base and keeping the collector to emitter path inactive. When the LDR is in a dark environment, its resistance is HIGH and current travels the base route instead, making the collector to emitter path to the LED active and allowing current to hit, travel through, and turn on the LED.

Student Activity: Path Mapping the Dark Detecting Circuit v2 under dark and bright conditions.

After explaining the educator background content above with their assembled circuits in front of them, instruct students to use their Day 8 Student Worksheet to describe what's happening in the circuit.

Circuitry with the Deluxe Distance Learning Kit:
Day 9

Content Area: Engineering/Science/Circuitry

Topic: Wiring circuits that use Solar Panels as a voltage source

Context: So far, you and your class have assembled circuits that utilize battery power (DC). All voltage sources, however, have their advantages and disadvantages. Battery power is nice and portable but relies on chemical reactions that will only produce electricity as long as there are unreacted reactants available. If you're not using rechargeable batteries, this means that eventually batteries will die and no longer be able to supply electricity. Wall outlet power is not portable, but will supply electricity as long as there's an active outlet. Some voltage sources like solar cells are both portable AND have the capacity to never run out of power as long as the correct conditions are present. Today's activities hinge on the assembly of circuits that utilize this renewable voltage source while testing some its basic characteristics.

Materials: 2 blinking red LEDs, 6-volt solar panel, self-sticking motor, Maker Tape, scissors, 4 resistors, Photoresistor (LDR), Googly Eyes, Foam Tape Strip, Printable Bug Template, Printable circuit template, Solar Bug Build Guide, Day 9 Worksheet, writing utensils

Educator Background: How solar cells work
In order to understand how solar-based electricity is generated, it is helpful for your students to understand what electricity actually is and why it travels. Electricity involves an understanding that all matter around us is made up of smaller and smaller units based around unique individual units called atoms. Atoms themselves are comprised of even smaller units called protons, neutrons and electrons. Different numbers of each of these particles accounts for the uniqueness of that particular atom/substance. Ordinarily, the protons and neutrons of an atom are clustered together in that atom's nucleus while a certain number of electrons (negatively charged) orbit around that nucleus. Thus, electrons are ALWAYS moving yet not everything around us is generating electricity. Electricity involves electrons moving but it's a different kind of movement than orbiting and it happens for a different reason. The electron movement that we call electricity involves electrons moving from THEIR atom to a NEIGHBORING atom because of a difference in concentration. Electrons, like heat and air pressure tend to move from places of higher concentration to places of lower concentration until equilibrium is established. THIS movement of electrons from places of higher concentration to lower is electricity.
Solar panels are set up with sandwiched layers of different materials with very precise electron concentrations. They work by allowing tiny particle of light called "photons" from a

source (ie the sun) to knock electrons of atoms free from their normal orbits around their nuclei so they may travel to nearby materials that have a comparatively lower concentration of those electrons. This creates a flow of electricity. Solar PANELS are made up of many, smaller units called photovoltaic cells. Many cells linked together make up a solar panel. Recall that generally, matter can be classified in relation to how easily electricity travels through it. Conductors allow electricity to flow through them while insulators do not. In labs however, we have discovered ways of taking materials that are normally insulators and slightly altering them to be "sort of conductive". We call this newer "in between" category of materials "semiconductors". Each photovoltaic cell is basically a sandwich made up of two slices of semi-conducting material, usually silicon. To make this sandwich of varying electron concentrations, manufacturers "dope" silicon with other materials, giving each slice of the sandwich a positive or negative electrical charge. To be precise, they add a bit of phosphorous into the top layer of silicon, which adds extra electrons, with a negative charge. The bottom layer gets a dose of boron, which results in fewer electrons, or a positive charge. The electron difference in these layers creates an electric field at the spot in between the silicon layers. Then, when the energy from a photon of sunlight knocks an electron free of its normal orbit, the electric field will push that electron out of the silicon junction toward the material with an electron deficiency. Metal conductive plates on the sides of the cell collect the electrons where they can be connected to a larger circuit like your battery.

Student Activity: Simple LED circuit powered by Solar Cell

Instruct your students to use the 1 LED Solar Circuit template and the materials they gathered to assemble it. This circuit will look familiar, though it utilizes the solar cell as the voltage source. It also uses a blinking red LED so that, when tested in sunlight, the working LEDs effect is more visible. Inform students that not all light sources output the same KIND of light. Once finished, students should test their circuit in direct sunlight. To do so, students should take care to first fold their circuit where shown on the template so that the LED is on the opposite side as the solar cell. With this done, the panel can be held to face the sunlight while the LED to be observed will be on the underside in the shade for ease of viewing. This may be difficult for your students to demonstrate to you at their computer stations because of proximity to sunlight. After this circuit has been successfully completed, students should disassemble it. Once disassembled, challenge your group to see who can come up with a circuit arrangement that successfully powers up both of their blinking red LEDs by activating/applying what they know about how to arrange multiple LEDs in series and parallel.

Student Activity: Solar Bug Build/Test

At this point, instruct students to find and examine their illustrated Solar Bug quick guide card (found in their kits). They should take inventory of which materials are needed for this build and separate them from what they should have gathered at the start of today's lesson. NOTE: The self-sticking motor included in the kits should still have the sticky backing and THIS is the project they will need to utilize it for. Once materials are ready, students may use the quick guide to help them build this simple solar project. There are 4 googly eyes that should be included in their kits, allowing students to choose either 3 or 4 contacts points (we call them "rumble feet") placed in non-specified locations. Encourage your students to make whatever choices in number and placement of feet that they want and then to test their bug in sunlight. They should use their Day 9 student worksheet to describe both their setup and the resulting movement of their bug. If you or your students might benefit from video instruction OR a larger format of these same instructions, you can direct students to the following link for reference:

https://browndoggadgets.dozuki.com/Guide/Solar+Bug+2.0/202

There are extension activities that can be completed with your students found at the same link. These activities DO require materials and equipment that your students are not likely to have at home. If presenting this material remotely, as intended, these will not be viable activities and are therfore not mentioned here. If you ARE presenting this material in person and have the tools included in those online lessons, you may enjoy exploring the other things this little bug can show you!

Circuitry with the Deluxe Distance Learning Kit: Day 10

Content Area: Engineering/Science/Circuitry

Topic: Application of concepts in device creation

Context: Throughout this curriculum, you and your students have worked mostly with circuits that were placed on paper without a real context for doing what they do. The Solar bug that you assembled yesterday is an example of a simple paper project that has circuitry integrated into it for a fun outcome (making a bug move). Today, your students will assemble their Bristlebots and also work on a more open-ended project that has them first create a 3-dimensional shape (a tube) that they can attach their choice of a couple of different circuits to the inside of. We call them "tube bots" and, depending upon the outcomes present in their chosen circuitry, students will then decorate the outside of the shape so that it becomes something that is enhanced by the circuit components. NOTE: Two of the circuitry options do include use of a self-sticking motor and this item is currently being used in the solar bug project. However, if a student wants to make their tube bot MOVE, they can pull this motor off of the Solar Bug and use either a clear or masking tape loop to reattach it to the new project like they had with the motor visualizer or with a dab of hot glue. If they'd prefer to keep their solar bug intact, they should choose circuitry for this project that is LED-based only.

Materials: Full kit contents, scissors, Coloring Utensils, Blank Tube Bot Templates, Bristlebot Quick Guide Card

Student Activity: Bristlebot Build

Your students will first complete a fun device that utilizes the (non-self-sticking) vibrating motor. Ask your students to find the Bristlebot Quick Guide card included in their kits and use it to see what they need from their kits in order to complete the project. Afterward, ask students to examine their motor. There is an aspect to this motor that is also present (though hidden) in the self-sticking motor that causes the vibration. Draw their attention to the weight attached to the motor spindle. When examined from straight on, students should notice that it is not uniformly shaped and so, its weight is also not evenly distributed. Ask students to recall their experiments with the motor visualizer disc. When pennies were placed around the perimeter of the disc, was the weight evenly distributed? Unless the pennies were placed in equal numbers directly across from one another on all sides of the disc, the distribution was likely to be uneven. Ask students to tell you about the motion of their visualizer disc when the motor and battery were directly in the center WITHOUT any pennies. Was weight distributed evenly THEN? Yes. It's true to say that the disc was spinning BUT, in the uneven distribution scenario with the pennies, the resulting OVERALL travel of device should have been pulling to one side or the opposite. The more the weight was centered, the less the disc wanted to travel left or right while spinning. The same thing is true of the unevenly shaped weight on this new motor's spindle. Because of its shape and placement on the motor spindle, the weight will also not spin evenly, resulting in vibration. This vibration, in turn, will cause the motion of their finished Bristlebot. Instruct your students to use their illustrated quick guide to assist them in assembling their Bristlebot. If you or your students might benefit from video instruction OR a larger format of these same instructions, you can direct students to the following link for reference:

https://browndoggadgets.dozuki.com/Guide/Bristlebot/2

Student Activity: Tube Bot Build

Your students' final project with this kit is a bit more open- ended than previous projects. They can choose any of the three templates provided OR experiment with their own circuit design (ignoring the circuit diagrams printed on the templates). Essentially what they will do is integrate one of their previous circuit concepts into the inside of a 3-D shape (a tube/cylinder). Depending on the circuit they chose, this might make the tube light up, move or both! Students should choose a template/circuit and then imagine/ execute a design on the outside of the tube around any LEDs present or with the motor motion in mind. The first option is a blank tube with one LED on the outside and a motor on the inside to make the object move. The second template is a parallel circuit with two LEDs on the outside. The third template has one LED hanging down from inside the lid of the project. It is designed so that students can cut shapes out of the tube before its final assembly so that, when finished, those shapes are back-lit like a Jack-O-Lantern. It may be helpful to have students open the following links to a variety of similar projects we made for the holidays to serve as inspiration and examples of what is meant by "designing around the circuit components". Again, it should be noted that two of the circuitry options do include use of a self-sticking motor and this item is currently being used in the solar bug project. However, if a student wants to make their tube bot MOVE, they can pull this motor off of the Solar Bug and use either a clear or masking tape loop to reattach it to the new project like they had with the motor visualizer or with a dab of hot glue. If they'd prefer to keep their solar bug intact, they should choose circuitry for this project that is LED-based only.

Check out the links on the next page for a few different tube bot projects.

Tubes of Terror

https://browndoggadgets.dozuki.com/Guide/Tubes+of+Terror/394

Christmas Tubes

https://browndoggadgets.dozuki.com/Guide/Christmas+Tubes/414

Thanksgiving Tubes

https://browndoggadgets.dozuki.com/Guide/Thanksgiving+Tubes/398

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