ELEMENTARY ELECTRICAL

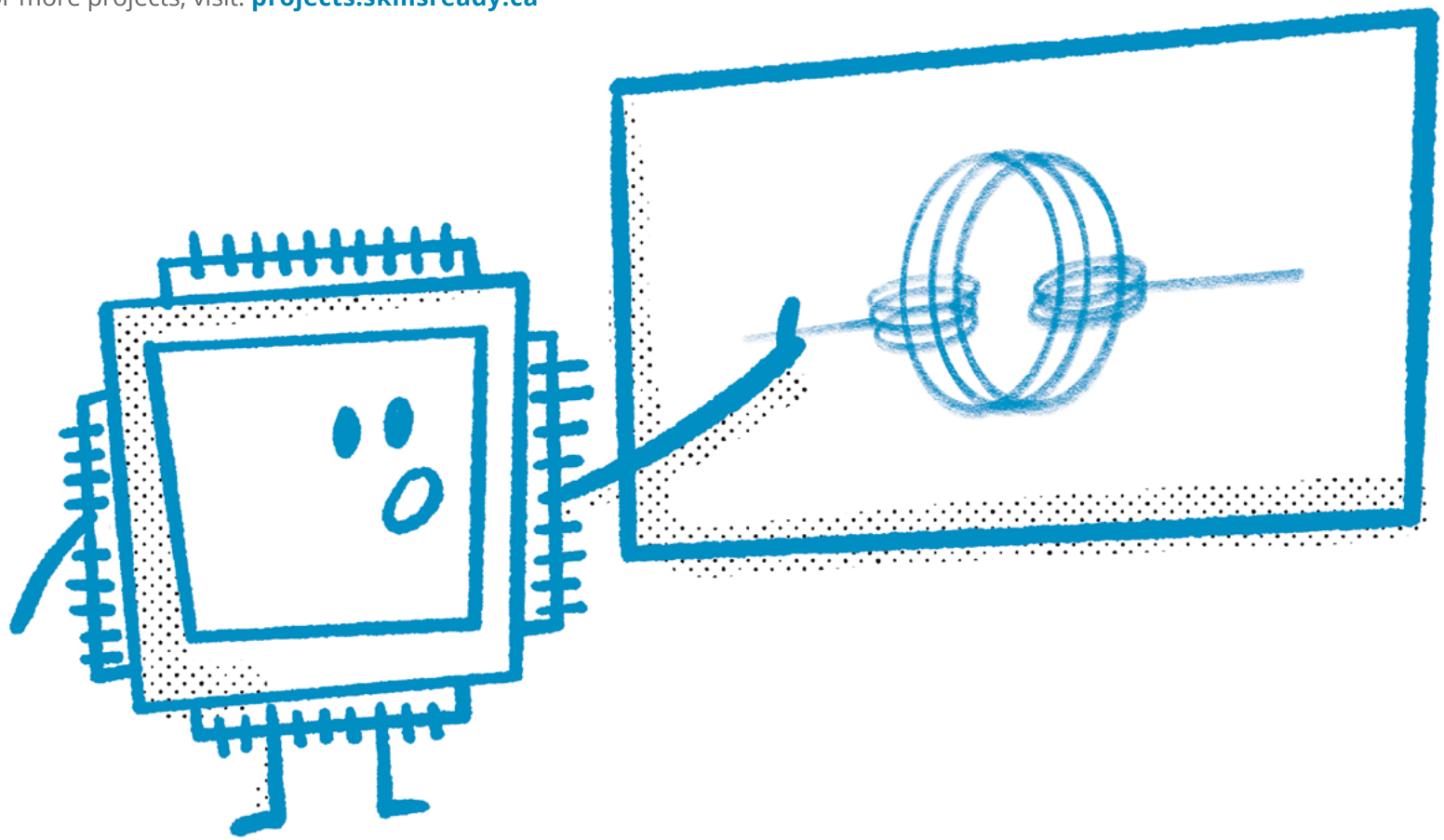
AN EXPLORATION OF CURRENTS AND VOLTS

skills READY

SEE THE POTENTIAL

This educator resource provides guidelines and best practices to follow when exploring beginner electrical projects and theory. These projects have been created to inspire students to learn new skills and expand their minds to learn new concepts. We believe that when you show someone what is possible, they will find a way to make it a reality.

For more projects, visit: **projects.skillsready.ca**



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SMALL BATTERY SAFETY GUIDELINES

Safety AND fun are both important parts of learning about and experimenting with electricity; risk shouldn't be a barrier to exploring your curiosity about electricity. Small batteries are everyday tools that are safely used in thousands of sensitive applications such as hearing aids, children's toys, and even musical birthday cards. The current generated by small batteries up to 9 volts is not enough to cause harm to a human.

However, we still need to respect batteries. This is for two reasons:

1) They contain acid which can damage your skin or eyes if it leaks out.
2) A battery can get very hot if the ends. ("Terminals") are connected without any resistance in the circuit to slow down the electricity. This is called a "short circuit". One example of a short circuit is when a piece of wire or metal connects a battery's terminals directly without sending the electricity through a light bulb, resistor, or motor.

- Always use healthy batteries for your projects. Inspect your batteries before using them; if they show signs of damage like dents or leaks, recycle them and choose a new battery instead.
- Avoid accidental short circuits. When you are finished using your batteries, remove them from your circuit and store them safely in their original packaging or a sectioned box separate from other batteries, wire, magnets, and other conductors such as metal tools.
- Battery acid can harm the environment. Recycle your used or damaged batteries by taking them to your local recycling center instead of throwing them in the garbage.
- Water is a great conductor of electricity! Keep your batteries dry.
- Curious babies and pets may eat small batteries and become very sick. Store batteries in a safe place, especially coin batteries, as these are easily swallowed.
- Not all batteries are rechargeable. Only put ones that say "rechargeable" on them in a battery charger. Recycle non-rechargeable batteries when they are out of energy.
- Batteries can get warm during normal use. Keep your workspace clean and don't let flammable materials such as fabrics and paper touch working batteries. Remember to disconnect all circuits before walking away from a project or workspace.

HOW TO USE A DIGITAL MULTIMETER

A multimeter is a tool used for taking measurements of electrical components and systems. It can tell you all sorts of useful and critical information about your circuits. Is your battery dead? Is your LED blown out? Is there a break in your circuit? Your multimeter can help answer all these questions and more!

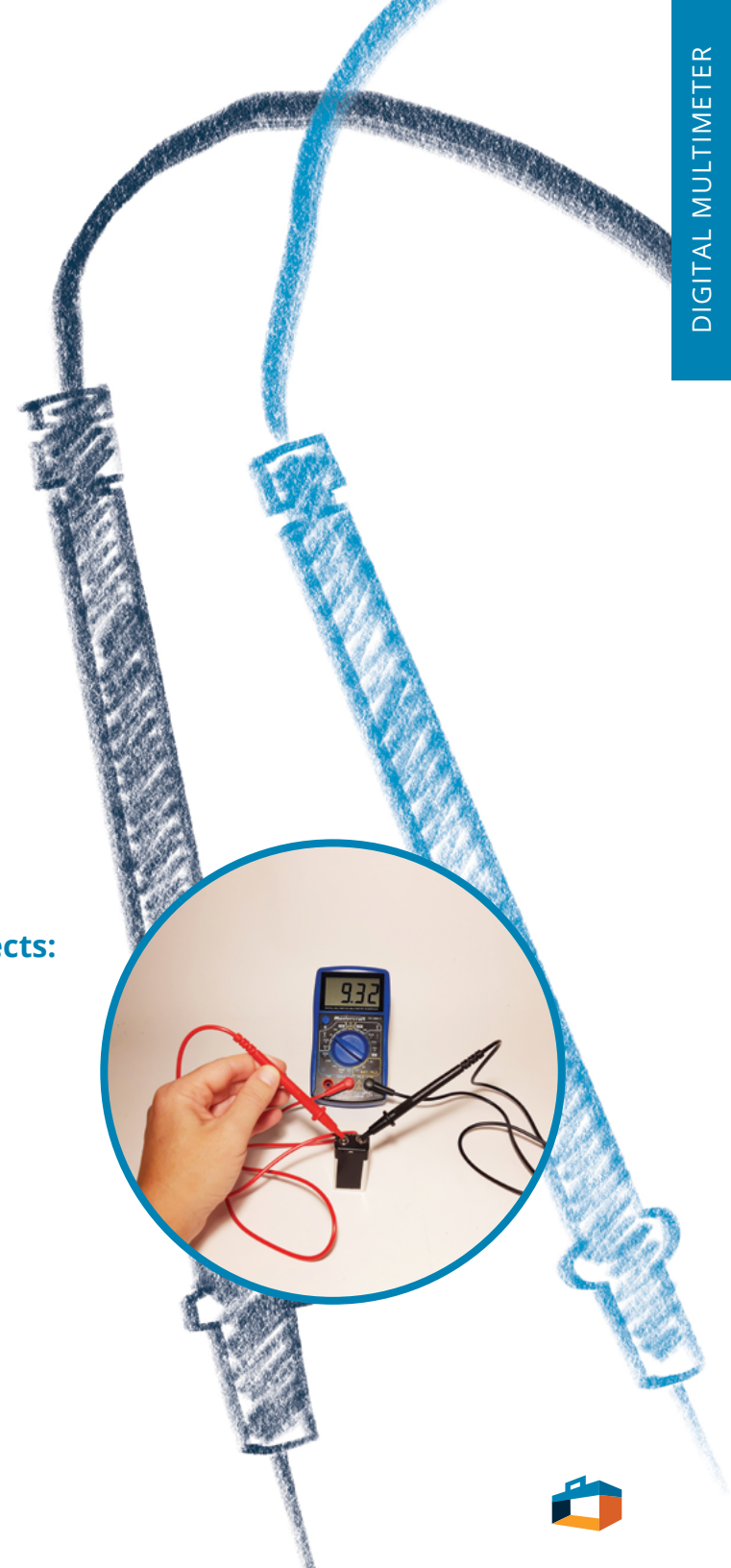
A multimeter has three main components:

1. **Display** - Measurement readings will be displayed here

2. **Selector knob** - Various measurement settings can be selected

3. **Leads** – these wires must be plugged into the meter for it to process a reading

Before using the multimeter, make sure the leads and the ports they plug into are undamaged, and when turning the knob, that the display turns on.



Simple tricks to use your multimeter for troubleshooting your projects:

Is my battery dead?

- Red cord in “VΩ”, black cord in “COM” (double check in manual if unclear)
- Switch the selector knob to “V” (try the “20” setting)
- Touch the lead points to the battery’s terminals.
- 9V batteries need replacing if 5.4V or below.
- AA, AAA, C, and D (1.5V) batteries need replacing if 0.8V or below.

Is my LED or light bulb blown?

- Red cord in “VΩ”, black cord in “COM” (double check in manual if unclear)
- Switch selector knob to symbol 
- Touch the lead points to the LED wires or light bulb terminals
- If your LED or bulb lights up and/or you hear a beep, then the LED or light bulb is ok
- If your LED or bulb doesn’t light up and/or you don’t hear a beep, reverse your lead points and try again (LEDs only work if the electricity goes in one specific direction)
- If you still don’t hear a beep, then your LED or bulb might be blown

Is my circuit broken?

- Disconnect or remove all batteries from your circuit
- Red cord in “VΩ”, black cord in “COM” (double check in manual if unclear)
- Switch the selector knob to symbol 
- Touch the lead points to bare wire on the ends of the circuit (this can be the two places where your battery terminals would usually contact)
- If you hear a beep, then you know the circuit is continuous; if you don’t hear a beep, check for breaks in your circuit

Does this object conduct electricity?

- Red cord in “VΩ”, black cord in “COM” (double check in manual if unclear)
- Switch selector knob to symbol
- Touch the lead points (about 1cm apart) to the object you want to check
- If you hear a beep, you know that the object is conductive; if you don’t hear a beep, the object is non-conductive (e.g., an eraser)

The settings of a multimeter include:

Voltmeter - Measures the voltage across the two leads.

Voltage is measured by placing the leads in parallel with the component to be measured. The leads can be placed across the source to measure the voltage of the entire circuit, or it can be placed across several components to measure a part of the circuit. The measurement is generally displayed in Volts (V) or millivolts (mV).

Ammeter - Measures the current passing through the leads.

Current is measured by placing the leads in series within the circuit. The measurement is generally displayed in Amps (A) or milliamps (mA).

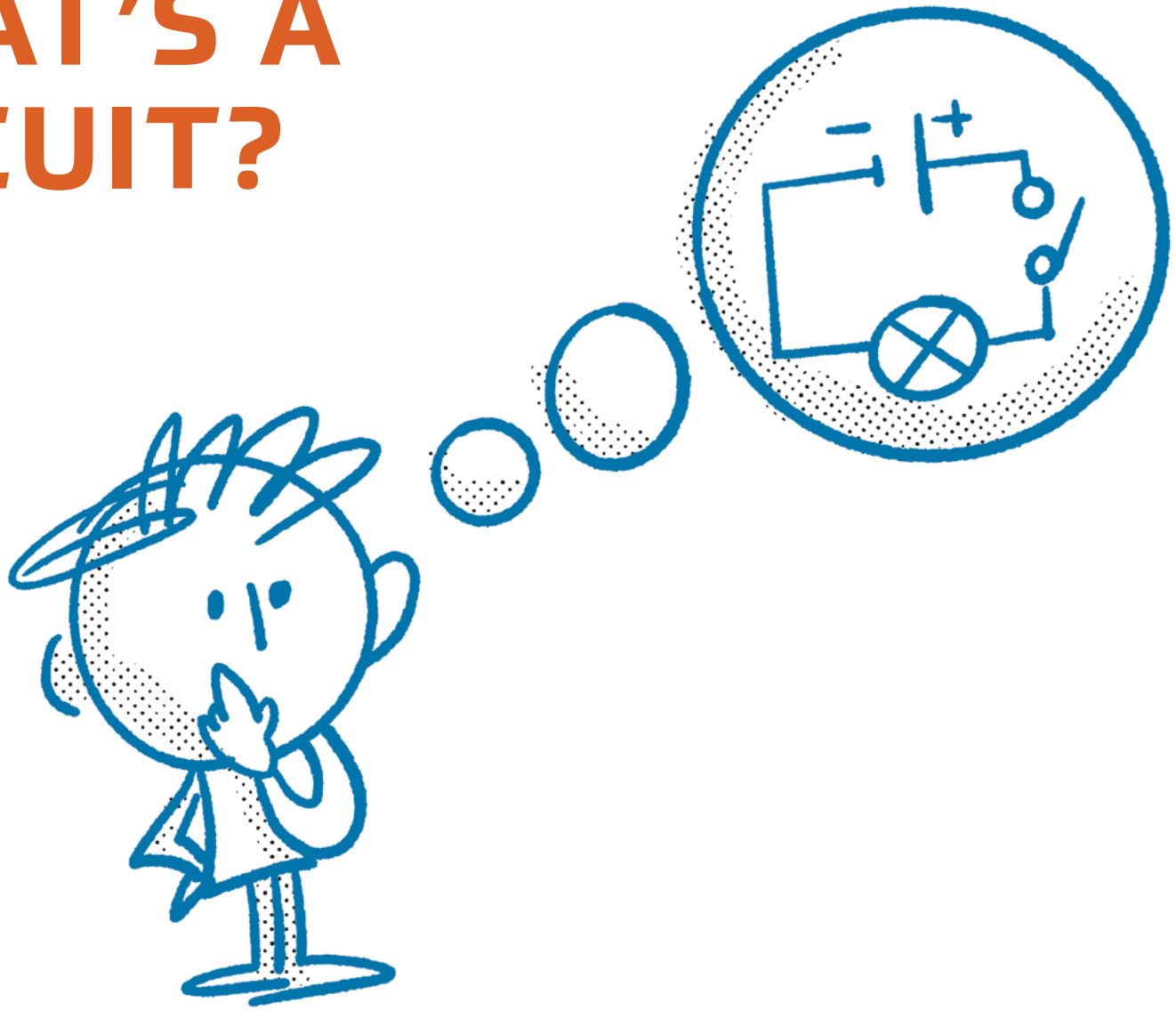
Ohm meter - Measures the electrical resistance of the component or circuit between the leads.

This metric gives you an idea of how electrically conductive a material or object is (a higher value means the object is less conductive). Disconnect the component you want to test and use the ohm meter as the power source. The measurement is displayed in Ohms (Ω) o r kilohms (kΩ). **Caution: Do not set a multimeter to this setting while it is in a live circuit**.

While many digital multimeters will automatically tune to an appropriate range, many multimeters must be set to a specific range for each of the various measurements. If you know what range, you are expecting you can set it directly to the desired range. Otherwise set it to the highest range and once the measurement is being taken switch down the ranges until you are getting a reading with at least 3 digits.

When finished with the multimeter turn the selector knob to the off setting.

WHAT'S A CIRCUIT?



CAREER BITE

Elisabeth Barrett

What is your trade, and do you have a specialty role within that trade?
I am an electrician. I have also done a security course which involves security cameras, alarms, card locks.

What 5 tools do you use the most?
My 5 most used tools would have to be my linesmen pliers, impact driver, wire strippers, level, and screwdriver.

How does your trade/work appear in people's everyday life?
Electrical work is all around you, from turning on a light switch to plugging in a device to charge, an electrician installed them.

How did you decide to pursue the trades?
I've always had an interest in the trades and working with my hands. I was fortunate enough to get my start through the WATT (Workplace Alternative Trades Training) program as financially I would not be able to do a foundations course.

How can someone get started in your trade?
There are many programs and bursaries out there for anyone wanting to get a start in the trades and help with schooling as well.

What is one piece of advice you'd want to give your past self or for someone wondering if a career in your trade might be for them?
My biggest regret with the trades is that I didn't start sooner.

My advice is: *Go for it, and if you are uncertain as to which trade you like the most there are trade sampler programs where you can experience what each trade does.*

LIT-UP LED

Building a circuit to light up an LED is a simple as sliding the diode's wires over a coin battery! Learning how electricity works in a safe, playful environment is a fun way to increase curiosity and confidence in working on electrical and electronic systems. Knowledge of simple battery-run DC systems can also help with visualization and troubleshooting car and boat wiring circuits and systems.

Teachers: this simple electrical investigation project also offers students an endless opportunity for applied design (a key curricular competency from both the ADST and science curricula in BC). Now that they have a tiny light, where can they imagine installing it? Could they use it to illuminate a toy or picture? Could it be used it as a flashlight or indicator light? For more advanced grades, you could have students designing switches to turn their light on and off, or they could incorporate the simple LED circuit into a device that solves a problem in their life. (Can it be used to light up the dark space in a cupboard? Could a series of several LEDs illuminate or indicate a path through a garden?)

Store your coin batteries in their original packaging so as not to accidentally create short circuits (which can result in battery damage or a fire hazard). Coin batteries are also harmful if swallowed; keep them away from pets and babies.

Materials

- Two or three lithium coin batteries (CR2032, CR2016 or similar)
- Two or three LEDs (3mm or 5mm, assorted colours)
- Electrical tape
- **Optional:** craft supplies such as construction paper, origami paper, paint, felt pens, cardboard, tape, etc.

Tools

- Just your hands!

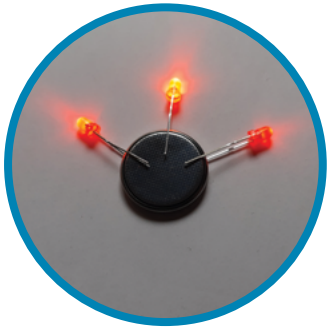
Process

1. Play with the coin batteries and LEDs; can you make the LEDs light up? What parts of the LED and battery need to touch to make it work?

2. Look up labelled diagrams of an LED and of a coin battery. Use the following words to explain what you observed or learned: LED, wire, short, long, positive (+), negative (-), battery, terminal.

3. **Troubleshooting:** Does your LED not light up? Try a new battery. Try a new LED. Flip the battery around. Try bending the LED wires so they make better connection with the battery.

4. Make something fun with your lit-up LEDs! Use a wrap of electrical tape to hold your LED wires in place on the battery, then use it in one of the following projects.

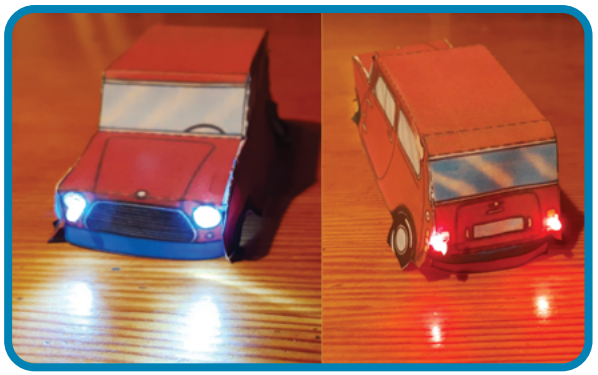


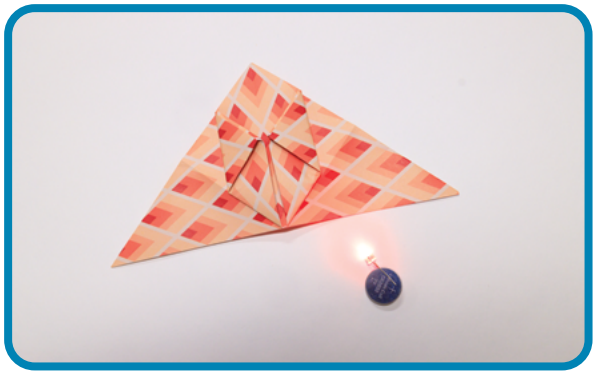
Project Ideas

5. Do you like origami? Fold a balloon or box and insert the lit-up LED into it before you finish folding it.

6. Do you like collage and painting? Make a “stained-glass” lantern: paste scraps of colourful tissue paper onto an empty glass jar using white glue and a paintbrush. Place your lit-up LED inside and let it shine!

7. Do you like vehicles? Choose and print a “printable paper car template” online, cut it out and tape it together, then add lit-up LEDs for headlights and taillights, etc.





8. Do you like boats? Make a boat model and use lit-up LEDs for port (red) and starboard (green) navigation lights.

9. Do you like sculpture? Use toilet paper tubes to make a house or dragon or robot or creature, decorate it, then cut or poke holes and insert your lit-up LED, hiding the battery inside the tube. The LEDs can become light-up eyes, or windows, or buttons - whatever you can imagine!

10. Do you like play acting or dressing up? Make a cardboard crown, decorate it, then poke holes and insert lit-up LEDs to make light-up jewels!

11. Can you think of other places you could be creative with your LED and battery?

Extension Challenges

- Design a new light-up toy using what you know about LEDs and batteries.
- Make a switch mechanism that can turn your LED on and off, so you don't have to take the LED and battery apart each time.
- Design a device that uses a lit-up LED to solve a problem in your daily life (is that hall closet too dark to find anything in?) or develop an imaginary or real product you could market to people (do dogs need light-up collars for night walks?).

CHARGE CARD

Make a light-up greeting card with a battery and LED! This project offers a downloadable pdf template for making a simple pull-tab switch (click the “download project” button on our projects website). Design your own cover and customize the colour of your LED to light it up.

Teachers, this is a great project for your science 4 students to make who are learning about “devices that transform energy” (chemical energy of battery -> electrical energy -> light energy!).

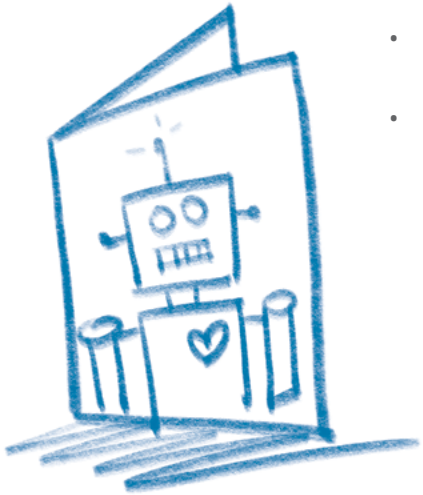
Make sure to keep the coin batteries away from babies and pets as they are dangerous if swallowed.

Materials

- One sheet of card stock or construction paper (colour of your choice)
- Printed pdf template (see downloads on this page)
- One 3mm LED (colour of your choice)
- One 3V coin battery (CR2016 or similar

Tools

- Pencil
- Ruler
- Scissors or utility knife
- Pen / felts / pencil crayons to decorate the card
- Clear tape



Procedure

1. Make the card: use your ruler and a pencil to mark out a ~5”x8” rectangle on some cardstock or construction paper. Cut it out and fold it in half.

2. Make a design or drawing on the front of your card that will incorporate a light near the centre – it could be a light-up heart in an animal like the example, or a little light-up apple in a tree, or a light-up yellow sunset, get creative! Think about which LED colour will work best with your design.

3. Cut out a small hole (1/2”x1/2” maximum) where you want the light to shine through. (Close to the centre of the card will work best with your switch). You can make this cutout the shape of whatever object it will represent, ie, a tiny heart, apple shape, circle, etc.

4. **Make the switch:** Print the downloadable pdf (note the scale, print to 100%) and cut out the two shapes from the template.

5. Fold the large shape on the line, and carefully cut a slit in the middle of the fold as shown.

6. Push the LED wires towards each other, then flare the ends out slightly, so it looks like the photo:

7. Slide the LED over the coin battery (if it doesn’t light up, turn the battery around and try again). Use two pieces of tape to secure the battery and LED to the template piece as shown.

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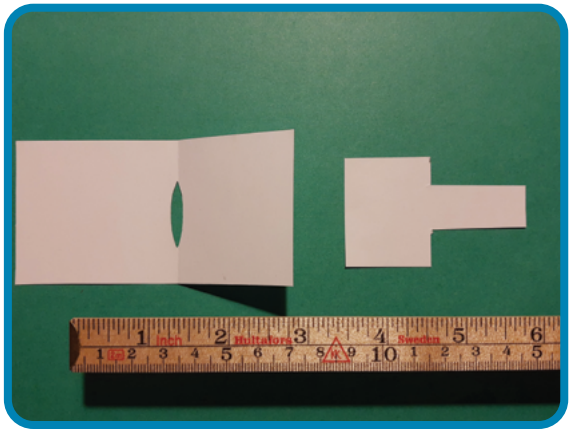

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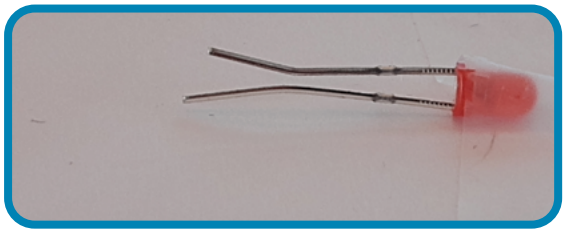

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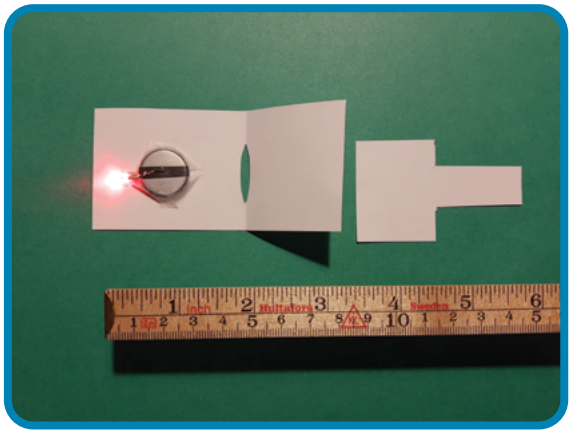


8. Push the narrow tab of the small template shape through the slit on the large piece and tuck the wide part under the LED wire so that it breaks the connection to the battery and the LED turns off. Fold the flap to the left again.

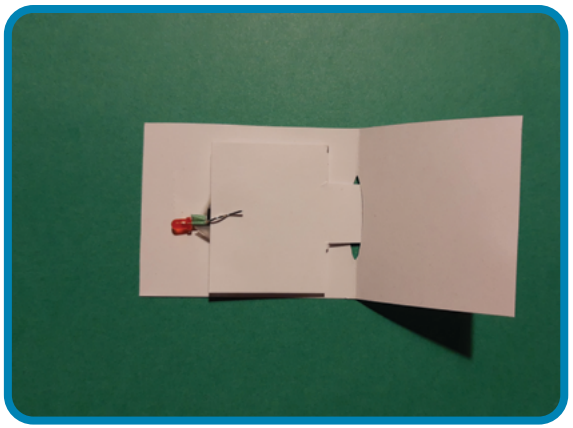
9. Pull the tab out to turn the light on and position the switch on the inside cover of the card so the LED is directly behind the hole you cut. Tape it down as shown, leaving the pull tab free to move.

10. Push the tab in to turn the light off. Draw a little arrow on the tab pointing to the right to indicate how to turn the card on.

11. Write a message inside and brighten someone's day!

Extension Challenges

- Make an envelope for your card.
- Can you design a card that turns on automatically when it opens? What kind of switch would you need to build?
- Look up "conductive tape circuits" and create a light-up card by making a circuit with the tape. Note: instead of buying expensive thin conductive tape, you can buy a wide roll of aluminum foil tape and cut it into strips.



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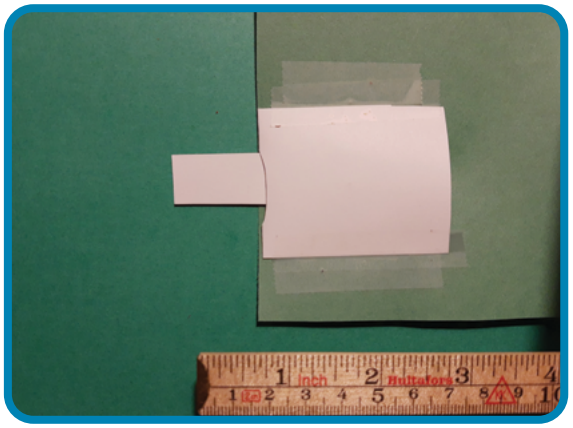

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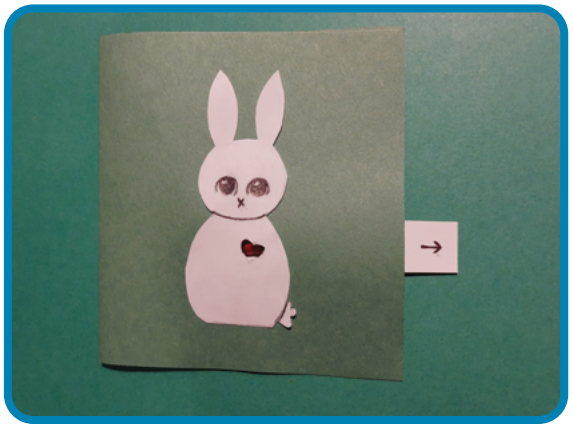

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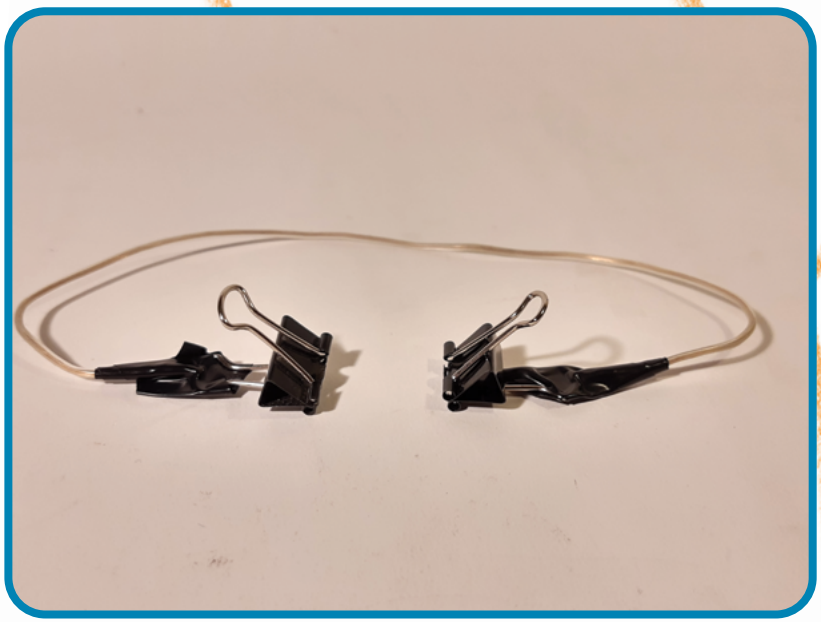
MAKE YOUR OWN CONNECTOR WIRES

Materials

- One 12” piece of Thermostat wire / speaker wire
- Two small binder clips
- One 4” piece of electrical tape

Tools

- Wire strippers
- Wire cutters
- Scissors



Procedure

1. Decide how long you want your connector wire to be (12” or so is a great length for the projects in this book). Cut your wire to 2” longer than your desired finished length.

2. Strip 1” of insulation from both ends of the wire.

3. String a binder clip’s silver handle over one of the bare wire ends. At 1” in, where the insulation ends, double the wire back and twist it back onto itself to secure the binder clip in place.

4. Cover the exposed wire with a few wraps of electrical tape, running a few wraps over the binder clip handle.

5. Repeat steps 3 and 4 for the other end of the wire.

6. Test your connector wire: use a multimeter’s continuity setting or clip your wire into a circuit with a resistor such as a simple motor or LED to see if it conducts current.

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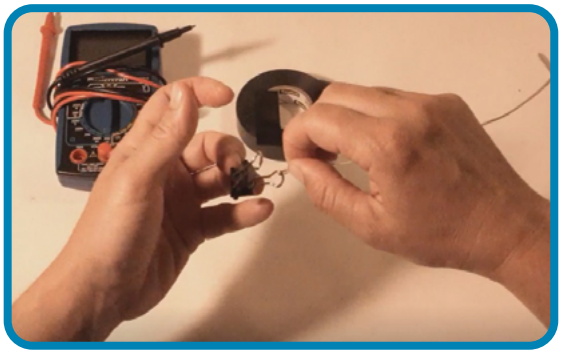

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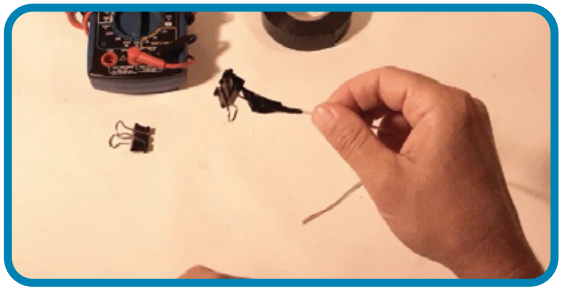

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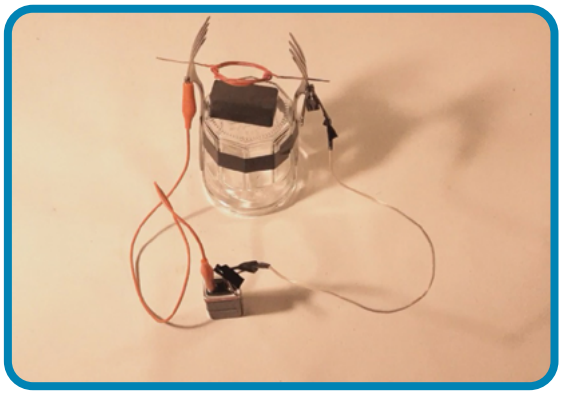


Extension Challenges

- Make a set of 10 connector wires (in different colours, if you can) to use while making the projects in this book.

- Customize your wire length for the different projects.

- Attach alligator clips on the ends instead of binder clips.

PENCIL RESISTORS

Some materials conduct electricity well and are used to transport electricity and information (like the copper wires in residential electrical work). Some materials hardly conduct electricity at all and can be used as insulators in PPE, such as on the soles of electricians' rubber safety boots.

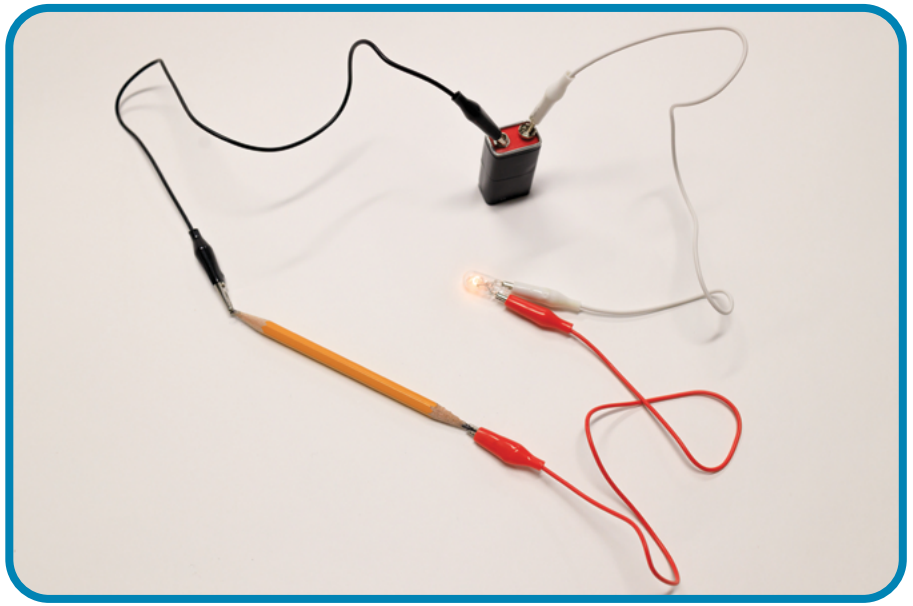
How well do you think graphite in a pencil conducts electricity? This project shows you how to make a simple circuit with a pencil and use the brightness of a light bulb to help you determine how much electricity is **actually flowing** through. This is an easy series circuit for beginners to build; neither the direction of the battery nor the order in which the components are connected matters.

Materials

- Five+ graphite pencils, new or used
- Three+ connector wires with alligator clip ends
- 9V battery
- Small incandescent light bulb (e.g., a 12V vehicle T3.25 miniature incandescent bulb is used in this example)

Tools

- Pencil sharpener
- **Optional:** multimeter, small hand saw



Process

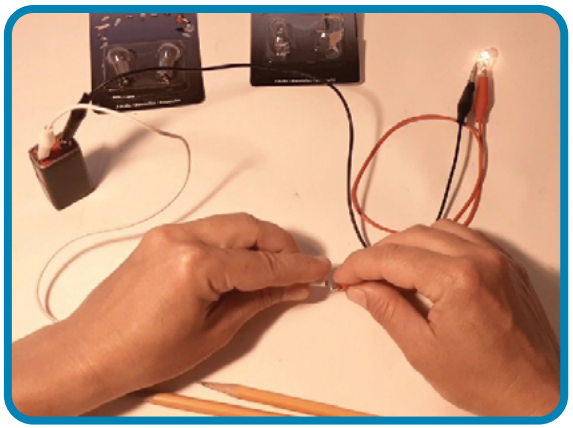
1. Sharpen both ends of each pencil (if necessary, snap or saw off the metal eraser ends first).

2. Wire up your circuit according to the photo (but don't add the pencil quite yet): clip one connector wire to one of the 9V terminals, a second connector wire from the 9V's other terminal to a light bulb terminal, and a third connector wire (black) to the light bulb's other terminal. Touch the two alligator clips together to see the bulb light up.

3. Next, clip the free alligator clips to either end of one pencil. If you want to see your bulb light up better, try turning the lights out. Does your light bulb light up again? Is it brighter or dimmer than in step 2? Why do you think this might be so? Where do you think the energy goes?

4. Add a second pencil to the circuit: how brightly do you think the bulb will shine? Attach the connector wires to the ends of separate pencils, then touch the free pencil ends together, making sure they press hard against each other. Does the bulb light up? Was your guess about the brightness correct?

5. Involve other people/students in your experimenting – give everyone their own pencil and insert them one at a time into the circuit, making sure their pencil graphite makes solid contact with their neighboring pencil(s). How many pencils does it take until you can't see the bulb lighting up anymore? Can you find a relationship between the number of pencils and the brightness of the bulb?



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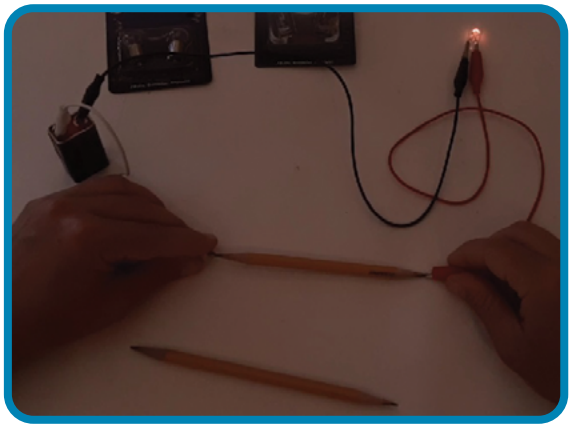

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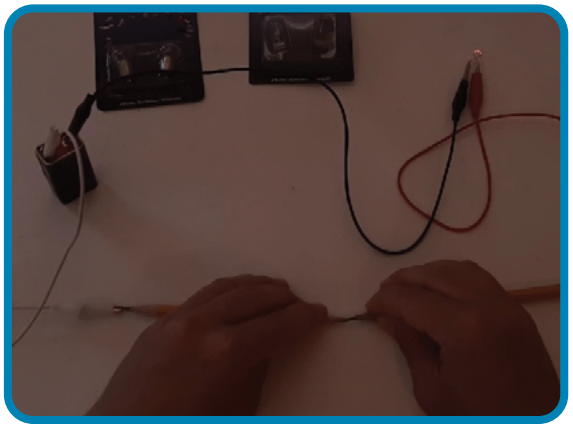

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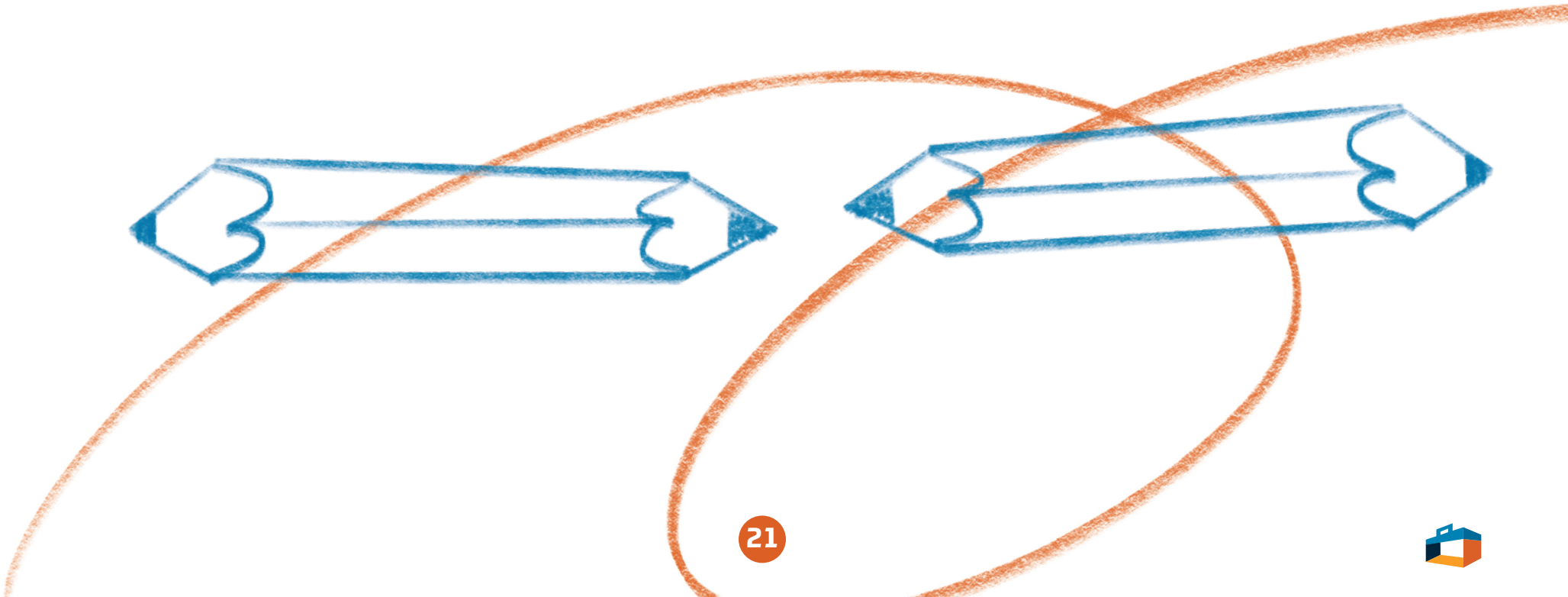
Troubleshooting

6. Make sure that the alligator clips are making tight contact with every part in the circuit.

7. Follow the circuit path with your finger and make sure that everything is connected, and that are no short circuits (places where electricity flows in unintended paths, such as if alligator clips are resting on each other from different places in the circuit).

8. Check the voltage of your battery with the multimeter and replace the battery if it reads less than 5.5 volts.

9. Try using shorter pencils if you want to add more volunteers to help make the circuit (it's not the number of pencils that is the limiting factor, but the total length of graphite inserted into the circuit).



Extension Challenges

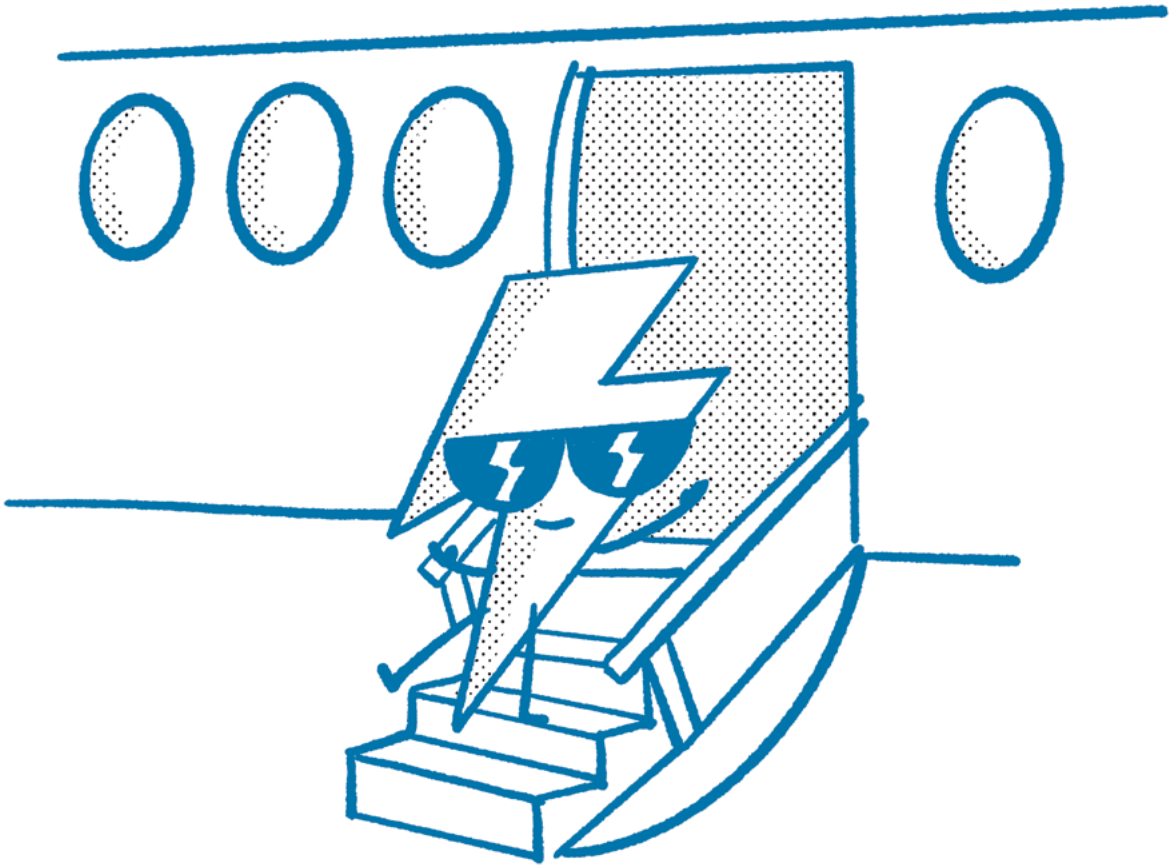
- Use the resistance function on your multimeter to measure the resistance (in Ohms Ω) of each component in your circuit (each pencil, each connecting wire, the light bulb, etc). Which item has the most resistance? Which has the least resistance? Do you predict that adding another connector wire would dim the bulb the same amount that adding another pencil would? Why or why not?

- Use the multimeter to measure the resistance of other found objects – what is the resistance of an eraser? A paperclip? A plastic pen? Which materials have the highest resistance? Which materials have the lowest resistance? Can you use your observations to make educated guesses about how resistant new objects will be?

- Instead of using the light bulb, insert a multimeter into your circuit and measure the current (in amps) flowing through your circuit. How does the number of amps of current change as pencils are added? Make a table to record your observations, then draw a graph to show your results.

- Research how to make a simple microphone using graphite sticks from a mechanical pencil, then build one. Could you design a simple telephone using this method?

WHERE DOES ELECTRICITY COME FROM?



CAREER BITE

Antonio White

Antonio White is currently an 8th term apprentice electrician working in the Electrical Marine Industry.

What trade are you working in, and can you briefly describe any kind of specialty role you may have within that trade?

I'm an electrician and I work on the Canadian Frigates down at Esquimalt Graving Dock. We provide power to the devices and equipment on the boats. We're doing a refit on older boats: taking out all the old wires and equipment and providing new ones, pulling cable through the boats, and hooking up things like generators and panels.

What 5 tools do you use the most?

Multibit screwdriver – instead of carrying around six different types of screwdrivers

Linesman pliers – They're good for gripping, twisting, bending, and cutting wire, can even be used as a hammer because they're so heavy.

Wire strippers – They're important for doing connections.

Adjustable wrench – It's useful in an industrial setting like the boats where you have lots of nuts and bolts to loosen and tighten.

Voltmeter – For safety, before you work on anything, you use the meter to check and make sure the power is dead.

How does your trade appear in people's everyday life?

There are things that people don't often even realize use electricity, like mechanical devices that need sensors that run on electricity. For example, there are pipes throughout the boats that have limit switches and sensors to make sure there's enough flow of water or whatever is going through the pipes, and we hook all that up electrically.

How did you decide to pursue the trades?

I played football growing up and I went pretty far with it, but injuries started taking a toll and I realized the best thing to do career-wise was to get to a trade. I ended up moving to Calgary and went to a company and they hired me on the spot: they started me out with the basics and gave me a set of tools. Once I was comfortable, I went to school and did my first year of electrical, and went from there.

What is one piece of advice you'd want to give your past self?

If I could go back in time, I would take that Youth Apprenticeship Program in school that they offered. I didn't know about the program, but I would have done football AND the Youth Apprenticeship Program if I could. Not only does it give you credits towards your diploma, it also gives you your level one apprenticeship. If you take that program, straight out of high school you already know the basics of electrical, and then you can go get a job and start right away. I wish I'd done that, because I would have been set up at a super young age.

ELECTRICAL FRUIT SALAD

The Electrical Fruit Salad is a fun way to get to know how a multimeter works by making a battery out of your lunch items!

Multimeters are indispensable tools used on trades jobsites every day. From assessing the voltage level of batteries on a boat, to confirming resistivity of household appliances, to checking for electrical continuity in a car wiring system, these tools are used to troubleshoot, diagnose, and test electrical systems in a multitude of settings. Getting familiar with how they work and what they can measure gives understanding to some of the many skills learned and used by tradespeople such as electricians and auto mechanics.

Teachers may also use this activity to experientially explore the science curriculum with students: Grade 4s learn about devices that convert energy (e.g., a fruit battery converting chemical energy to electrical energy!), grade 5s learn about solutions and solubility (how the acid levels in the different foods conduct electricity to varying extents), and grade 7s learn how electricity is generated and the environmental impacts of the different methods.

Materials

- **Various juicy foods**: fruits, vegetables, tubers, apples, lemons, potatoes, cucumbers, bananas, limes, oranges, strawberries, kiwis, whatever you choose to test! Olives? Beets? Yams? Test them all!
- Five or more connector wires with alligator clip ends
- 2” pieces of thick copper wire (one per food item)
- Galvanized (zinc) roofing nails (one per food item)
- One 3mm red LED bulb

Tools

- Multimeter
- Damp cloth
- Wire cutters
- Notebook
- Pencil

Process

1. Choose which piece of food you want to make your battery out of. Insert your copper wire electrode and your galvanized zinc nail electrode, making sure they do not connect to one another inside the fruit.

2. Clip one connector wire to the copper wire, and another connector wire to the nail.

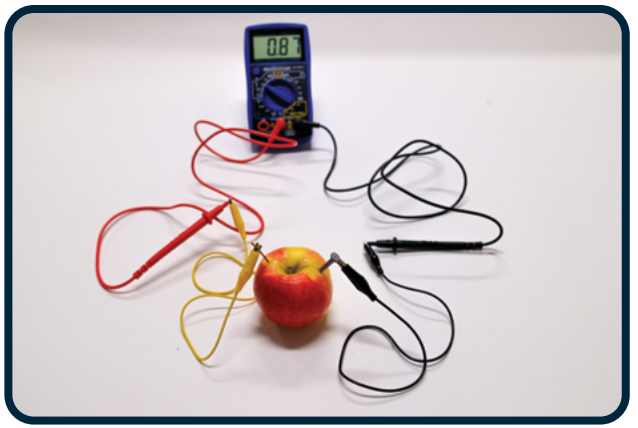
3. Set up your multimeter to read volts: plug the black cord into “COM”, and the red cord into “VΩ”. Set it to read “DC” volts at the largest number it can.

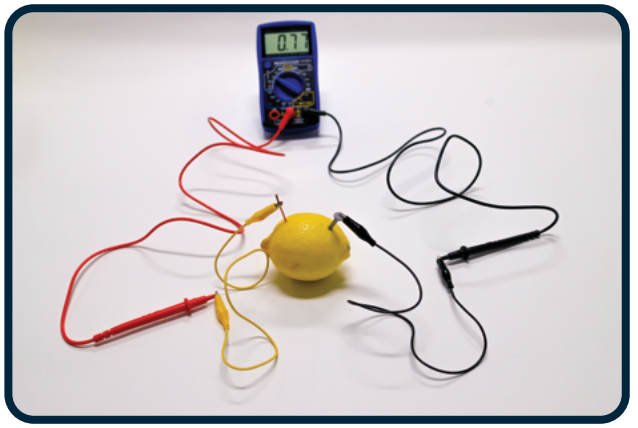
4. Clip the free ends of the wires to your multimeter probe ends. If no numbers appear on the screen, switch the multimeter down to read smaller voltage amounts until you get numbers appearing (the “20” will usually work, if your multimeter has it). Your fruit is now a battery!

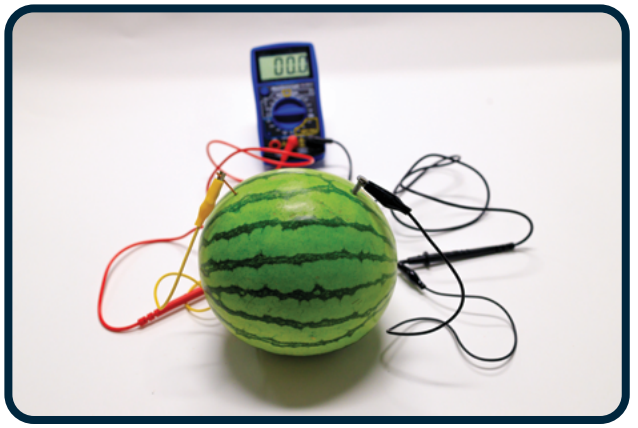
5. In your notebook, write down the type of fruit you are testing, the settings on the multimeter that you are on, and the number of volts it reads. One at a time, try out all the different pieces of food you have collected!

6. Try wiring up more than one piece of fruit in a row (this is called “in series”). Make sure that you attach copper anodes to zinc anodes (don’t attach copper to copper or zinc to zinc, as you want all the electron flow to go in the same direction). Record in your notebook the types of food connected and the voltage reading.

7. Try connecting the LED into your circuit to see if you can make it light up! (Instead of clipping the connector wires to the multimeter probes,

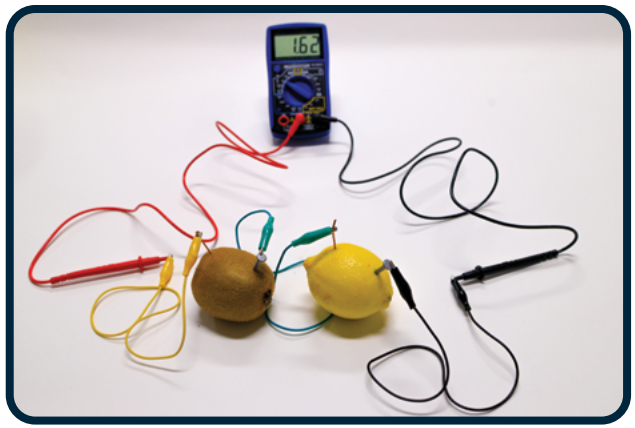






clip them to the LED wires instead). How many fruits in series does it need to power up? Note: LEDs need electricity to flow in one specific direction – each time you test the LED, test it in both orientations by reversing it and attaching the alligator clips to the opposite LED wires.

8. Clean up by turning off the multimeter, disconnecting all the wires, then wiping down the alligator clips and table with a damp cloth. Remove the metal from the foods and save the nails and wire for another project. You can't be sure that your wire and nails were food-safe and clean before starting, so compost your foods when you're finished - do not eat them.

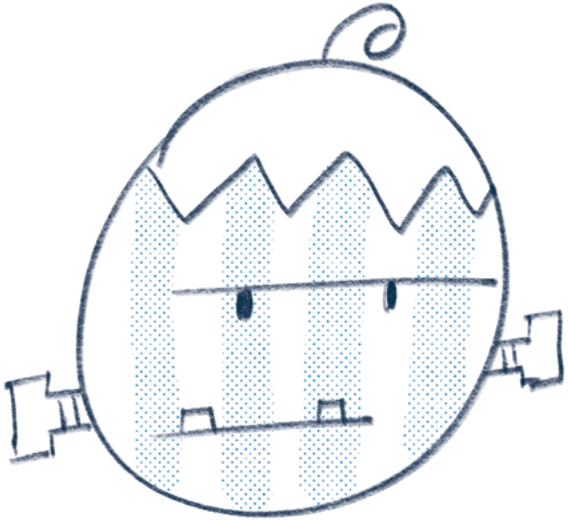


Troubleshooting

- If the copper wire is too thin to push into the food easily, poke a pilot hole with the nail first.

- If the multimeter is showing no voltage while your food is connected, try turning the multimeter dial to read a smaller voltage. You can also check that the multimeter is working by turning the dial to the continuity selection and connecting the probe tips together (if there are no numbers or no beep noise, your multimeter might need a new battery).

- If your LED won't light up, try reversing it as it will light up only when the electricity is flowing in one specific direction. Also, try adding more fruit in series to up the voltage.



Extension Challenges

- When you connect foods together in series, do you notice a pattern in the voltage amount? Can you use this pattern to predict the voltage any two foods will produce when you connect them in series?
- Try wiring up different liquids with your copper and zinc electrodes by taping them to the inside of a small plastic cup, submerging the ends in the liquid. Can you make a battery out of a cup of vinegar? Fruit juice? Sea water?
- Explore using different metals other than copper and zinc. What other metals might turn the fruit into a battery? Do they produce the same amount of voltage in the same fruit as the copper and zinc electrodes do?

THE ENERGY SHAKE

There are many ways to make electricity; one of the most common ways is to move magnets and wire coils relative to each other. In this project, you will make an electric generator that lights up some LEDs as you shake magnets past wire coils, no batteries required!

This project introduces wire winding, a key technique of the motor winding trade, an integral process in making motors and generators. Note: it is easiest to wind the wire directly from the spool onto your project by placing a pencil through the spool and resting it over the rim of a mug. 300 wraps (about 100' of 28AWG wire) should be enough to light up a 3mm red LED. If you have 150' of wire (enough for 500 wraps), your LEDs will light up even more brightly.

Make sure to keep the strong magnets used in this project away from pets and small children, as they can cause complications if swallowed. Be sure to also keep them away from your electronics and any bank cards.

Teachers: this project offers strong links to the BC curriculum, including making "energy shakes" with your science grade 4s as examples of devices that transform energy, or with your science 7s as a way to illustrate the different methods of generating electricity (and associated environmental impacts).

Materials

- ~2 1/2" x 6" cardstock
- Minimum 100' ~28 AWG enameled magnet wire (enough for 300-500 wraps)
- Two 3mm red LED bulbs
- Three 3/4" neodymium disc magnets
- Scrap paper
- Tape (any type)
- Sandpaper, any grit

Tools

- Wire strippers with cutters
- pencil
- Measuring tape
- ~7/8" diameter x ~8" long cylindrical found object (e.g. a candle or dowel)
- **Optional:** soldering iron and fine electrical solder

Procedure

1. Combine your two LEDs in “parallel”. Splay their wires apart slightly and put the bulbs side by side. Twist one LED’s short wire and the other LED’s long wire together. Next, twist the remaining two wires together. Splay the twisted legs apart so that no parts of the two “legs” are touching the other, or you will create a short circuit and the LEDs won’t light up.

2. Wrap the cardboard around the found round object to make a long tube. Use tape to hold the cardboard tube together but be careful not to tape the cardboard onto the object below. Leave the tube on the object for now.

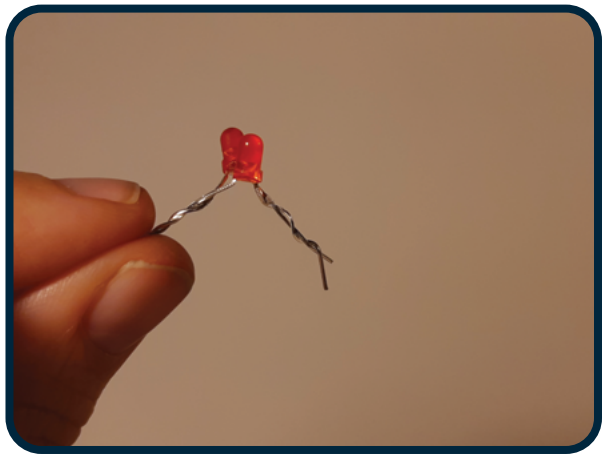
3. Halfway down the tube, tape the free end of the wire on as shown, leaving a 2” tail. Thread your wire spool onto a pencil and place it over a mug (or ask a friend to hold onto the pencil ends for you) while you wrap the wire onto your project.

4. Wrap the wire around your tube, keeping within about 1” of the middle of the tube.

5. Make between 300 and 500 wraps, depending on how much wire you have. Lay a strip of tape over the last wrap, and clip the wire, leaving a 2” tail.

6. Use the sandpaper to scrape off the enamel coating from the last 1” of each wire end.

7. Twist one bare wire end to one of the LED twisted legs. Attach the other wire end to the other LED twisted leg. To prevent a short circuit, make sure none of the bare wires or LED legs from one side/end are touching bare wires or LED legs from the other side/end.



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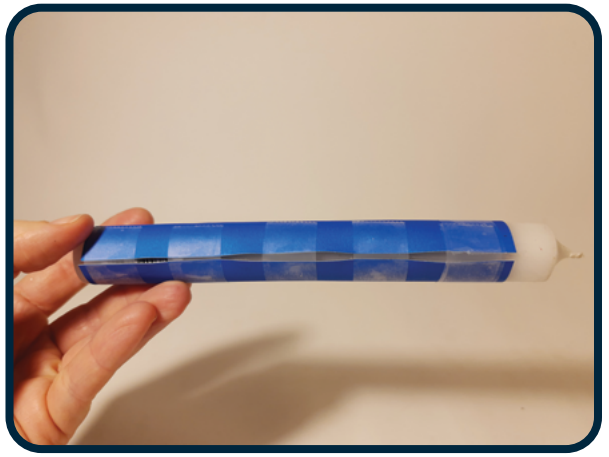

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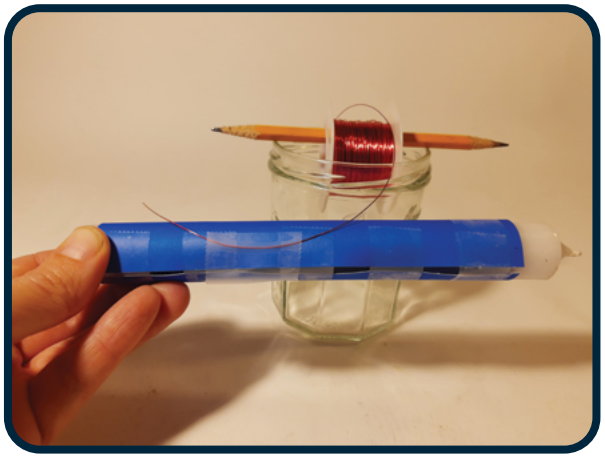

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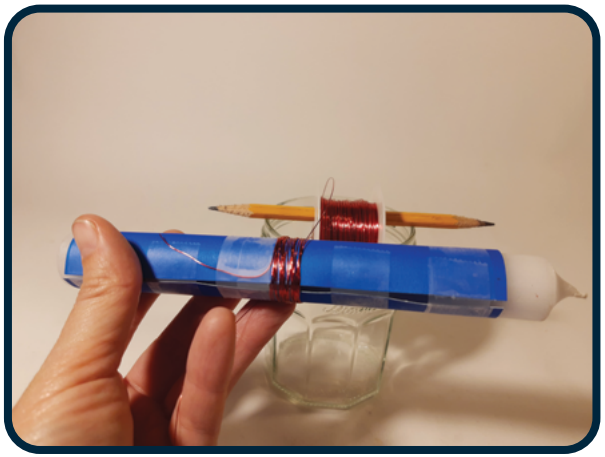

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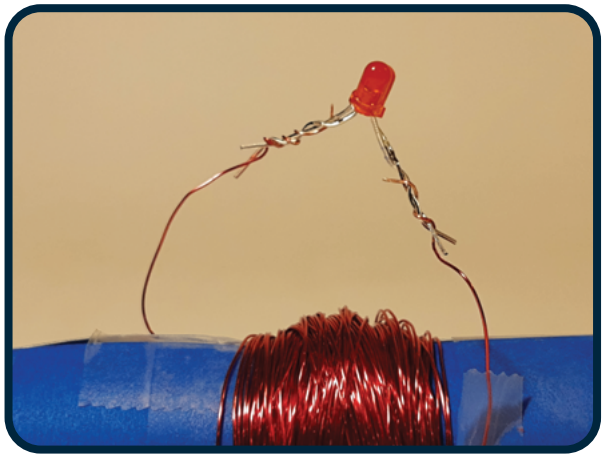

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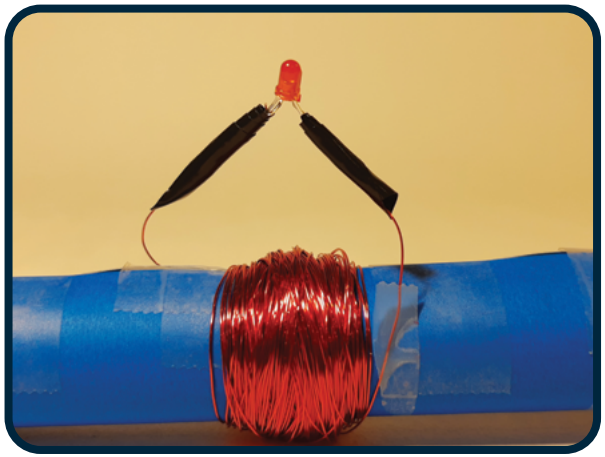

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8. Wrap these connections with tape. (Note: if you have access to solder and a soldering iron, soldering these connections would make them even stronger).

9. Tape the LED assembly securely to the tube, leaving the bulbs uncovered.

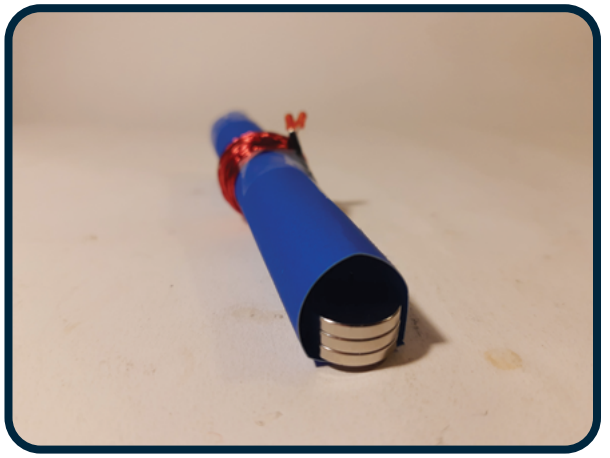
10. Pull the tube off the object. Crumple up some scrap paper into a small ball then tape it to one end of the tube to close it.

11. Stack your magnets and slide them into the tube.

12. **Optional:** if your magnets are a lot smaller in diameter than your tube, create a cylindrical cuff of cardstock to tape them into tightly so that they remain aligned inside the tube instead of tumbling around randomly. This will help make your energy shake more efficient and your LEDs glow brighter. See the photo for how to line the batteries up in the cardstock cuff.

13. Close up the other end of the tube with another crumpled piece of paper, then tape into place.

14. Shake your generator back and forth so the magnets whizz past the wire wraps and watch what happens!



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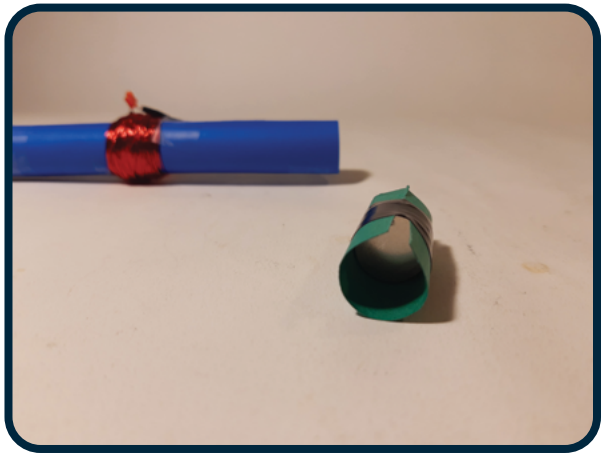

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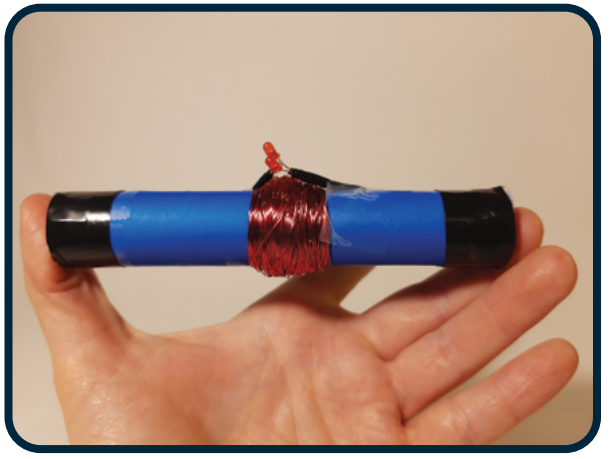

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Troubleshooting

Do your LEDs not light up?

- Try shaking faster.
- Observe your generator in a darker room; sometimes the LEDs light up only faintly.
- Check for a short circuit: pull the LED bulbs apart slightly so that there is no unintended crossing of wires (the twisted ends should be the only wires touching each other)
- Try starting again with a new piece of wire, adding another 100 or 200 wraps than you did on your previous design.
- Add another magnet (or more!) to your stack.

Extension Challenges

- Figure out how slowly you can shake the generator and still have the lights go on. Calculate the “shakes per minute” by counting how many shakes you do in 15 seconds, then multiply that number by 4. Is it faster than your heart rate?
- Replace your red LEDs with different colours. Do they light up with the same shake rate as the red ones? Why do you think this might be?
- Design a shake generator that has more LEDs on it.
- Decorate your generator with stickers or paints, or papier mache the whole thing!
- Attach a multimeter to your shake generator to see how much voltage you produce with each shake (connect one probe to each wire end using connector wires with alligator clip ends). Look up “active buzzers” to see if you make enough voltage to make one work: try wiring one in the same way you did the LEDs.

MAKING ELECTRICITY

Electric motors are amazing devices that transform electrical energy into kinetic energy. For example, when you plug a kitchen mixer into an outlet, it's motor will transform electrical energy into kinetic energy which you can use to scramble eggs!

Did you know that electric motors can also transform energy in the OPPOSITE direction? If you spin an electric motor's axle, it will transform the kinetic energy of that movement into electrical energy for you to use! Used in this way, a motor is called a generator.

In this project, you will turn a hobby motor into a generator. What sources of kinetic energy can you use to spin the axle and make the electricity to light up LEDs? What happens when you spin the axle in the opposite direction?

Materials

- Hobby motor with lead wires attached (ones rated 1.5V - 6V work)
- Electrical tape
- 1 x 3mm red LED
- 1 x 3mm yellow LED
- Cork from a bottle
- Fork
- 3' of string or thin ribbon
- 3' of strong thread or fishing line
- **Optional:** fine electrical solder, plastic propellor that fits on the hobby motor axle

Tools

- Wire strippers
- Utility knife
- Scissors
- **Optional:** soldering iron

Procedure

Make your generator from a hobby motor.

1. Combine your two LEDs in “parallel”. Twist the red LED’s short wire and the yellow LED’s long wire together. Next, twist the remaining two LED wires together, making sure that the two twisted legs are separate and no part of one leg is touching the other.

2. Strip the last ½” of insulation off the motor’s lead wires. The motor, when used to transform kinetic energy to electrical energy, will now become a generator.

3. Twist the bare copper end of one of the generator’s wires around one of the twisted LED legs. Wrap a small piece of electrical tape around the bare wire twist to insulate it.

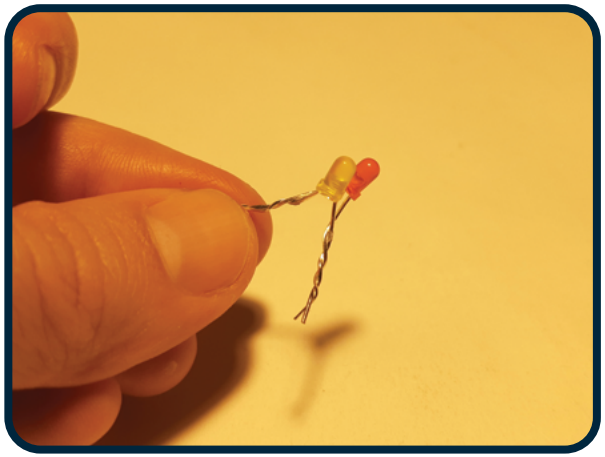
4. Repeat for the other LED legs. You can also solder these joints to make them more permanent if you have a soldering iron and fine electrical solder.

5. Place the generator on the fork, with the axle poking through the tines as shown. Making sure to keep the axle free, wind electrical tape around the motor and fork to secure it in place.

6. Secure your LEDs and wires in place with another wrap of electrical tape.

Try different methods to get your axle spinning fast enough to power the LEDs:

7. Fit a propellor over the axle and blow over it. Which LED lights up?



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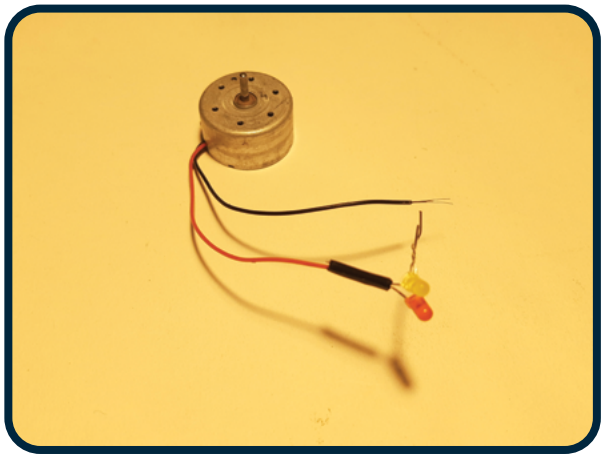

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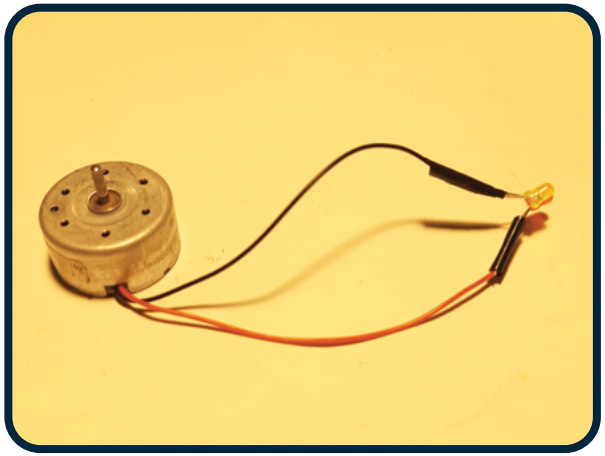

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8. **Make a hub:** Either use a whole cork or cut a cork in half using your utility knife to make two shorter cylinders. Push the axle into the centre of the cork. Leave at least 1/16" of clearance between the motor case and the cork to allow it to spin freely. Experiment with ways to make the hub spin!

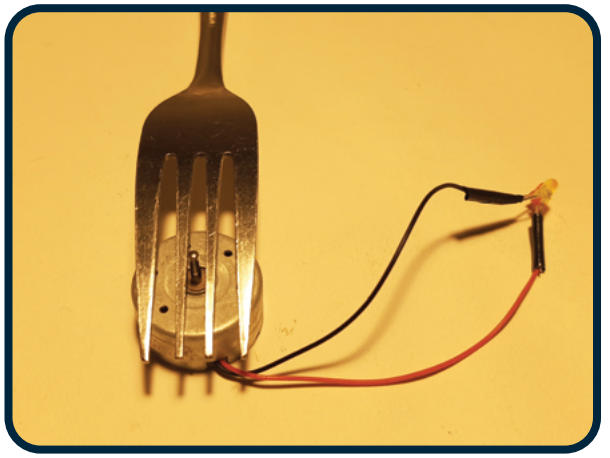
9. Get a friend to hold up the back end of a bike and push the pedal around for you. Gently touch the cork hub to the tire to get it spinning. What happens? Try putting the fork on the other side of the tire and spinning the hub the other direction. What is different this time? Why do you think this is happening?

10. Wrap the string or ribbon around the cork hub, securing the first wrap under subsequent ones, until all you have is a 2" tail remaining. Now, hold the fork tight in one hand and pull the string quickly. What happens to the LEDs?

11. Make a bow with a stick and string, and customize a cork hub by cutting a V-shaped groove around the side for the string to run in. Make one string-wrap around the cork, then run the bow back and forth to spin the hub.

12. Put a plastic or cork hub on a second hobby motor, then attach it to a battery. Push the cork hub of your fork generator to the second hobby motor hub to make it spin.

13. What other attachments can you think of to add to the cork hub to make it spin? Are there other sources of kinetic energy that you can imagine utilizing with your generator to power your LEDs?



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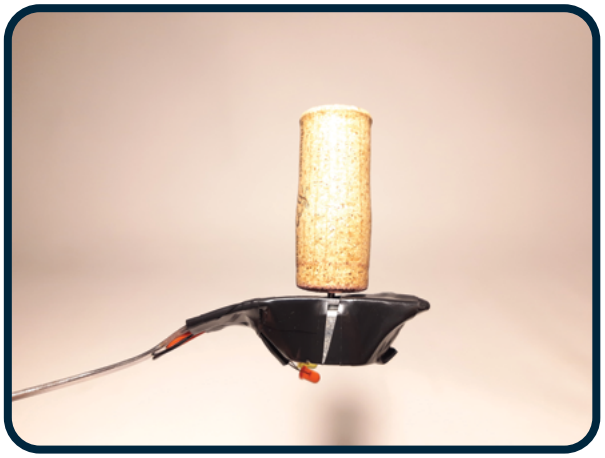

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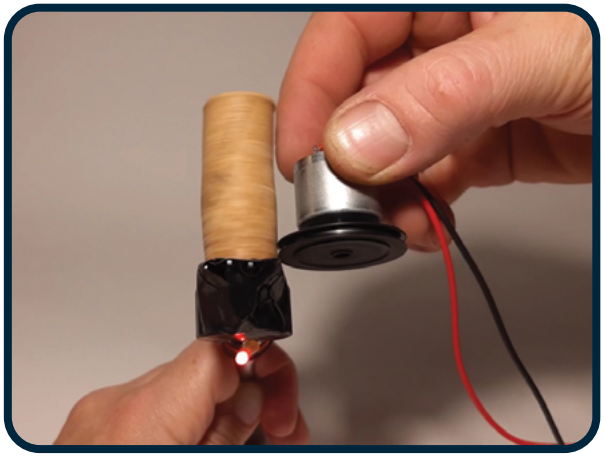

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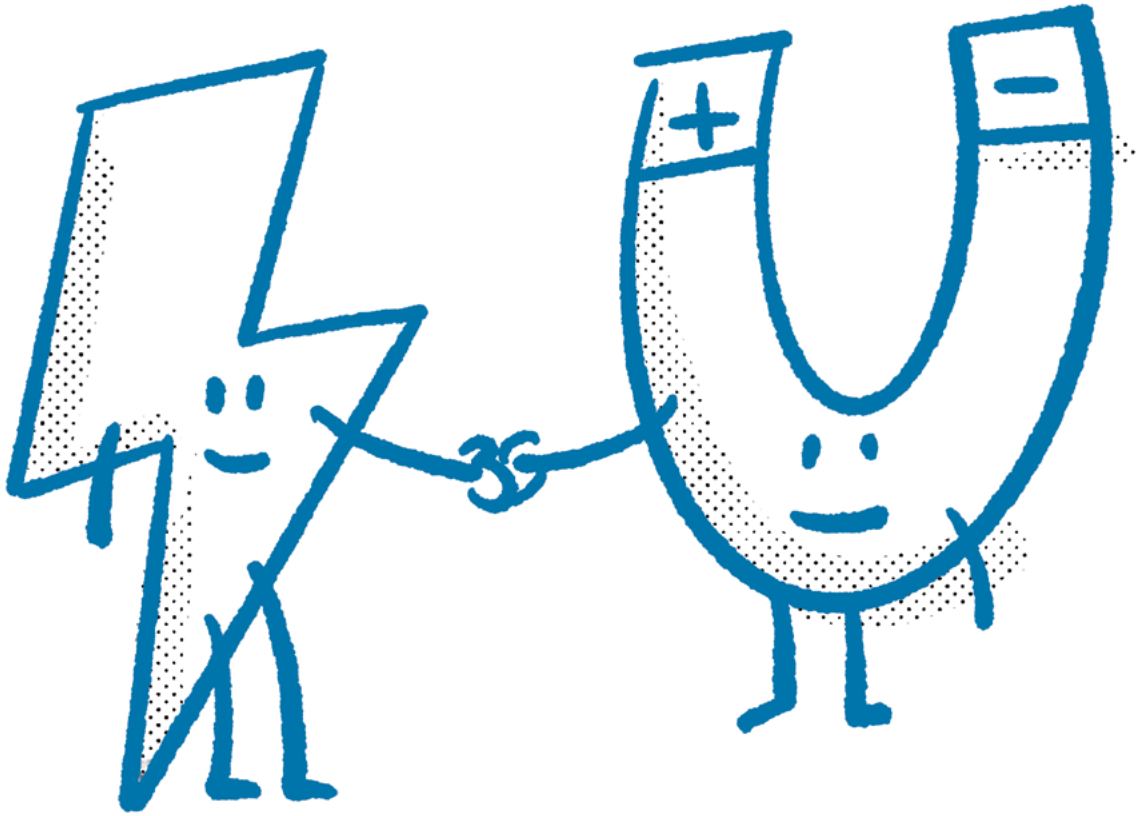
Troubleshooting

- Check that your motor is working before you start by checking that it spins when you connect the wires to the ends of a 1.5V battery (A, AA, C, or D battery).
- Try spinning the axle faster.

Extension Challenges

- Make a “game of strength” toy. Wrap the cork hub with ribbon to wind it up. Link several LEDs up in series: make an LED chain by twisting each LED’s positive wire to the neighboring LED’s negative wire, then attaching the first and last LEDs’ wires to the generator’s wires with connector wires. See how many LEDs you need to add to make it difficult to pull the string fast enough to light them up, then test the strength of your friends to see who can light your LEDs.
- Design a water wheel for your generator. You may have to hook it up using a belt between two hubs if you want your axle to spin fast enough.

ELECTRICITY MEETS MAGNETISM



CAREER BITE

Mike Van Hellemond

What is your trade, and do you have any specialty role within that trade?

I have obtained Red Seal Endorsements for Electrician, Electric Rewind Mechanic, Millwright, and C level welding. I was able to obtain these through the support of the International Brotherhood of Electrical Workers (IBEW) training opportunities during my career since 1991.

What 5 tools do you use the most?

I use a boom truck for placing large switches and breakers in high voltage switch yards and substations. Common hand tools I use are lineman pliers, wire strippers, socket/combination and torque wrenches, hammer, screw drivers and a tape measure.

How does your trade/work appear in people's everyday life?

Electricity is everywhere, used in commercial, residential, and industrial settings.

How did you decide to pursue the trades?

My dad was a DIY advocate so by the time I was old enough to make my own decisions I decided I should learn how to do both heavy lifting and electrical work properly because it hurts when they're done incorrectly!

What is some advice you'd want to give someone wondering if a career in electrical might be for them?

I would say to show up on time, be professional and ethical in your work, wear proper PPE at all times, upgrade your skills, take leadership training, and join a union asap!

If you're interested in industrial work, be prepared for heavy work in all seasons (-40°C to +40°C). Residential and commercial work tends to be lighter work indoors, but at a much faster pace. Industrial wage packages are higher; however, periods of unemployment can last many months between projects; create a financial plan and live within your means.

ELECTROMAGNET

Explore the fascinating relationship between electricity and magnetism by building your very own electromagnet. Solenoids are an example of common devices that use electromagnets like the one in this project to lock doors, engage starter motors on engines, and regulate fluid flow in pipe and hose system.

This project offers fun opportunities to design scientific experiments to study what variables make an electromagnet stronger, the measurable dependent variable being the number of pins or other metal objects your magnet can lift at any one time.

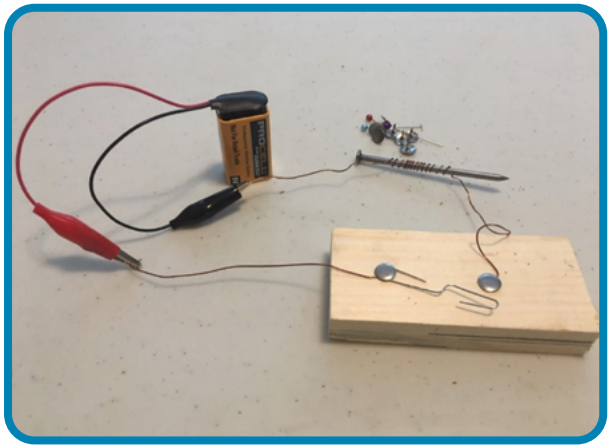
Be sure to disconnect your battery when you are not using the electromagnet to avoid battery overheating.

Materials

- One piece 1” x 3” x 4” Common Fir or equivalent softwood
- One 6” piece of 24 gauge (0.5 mm) enamelled copper wire
- One 12” piece of 24 gauge (0.5 mm) enamelled copper wire
- Sandpaper or emery cloth
- 9V battery
- 9V Battery connector with alligator clip ends
- Two thumb tacks
- Large paper clip
- One 3” common nail (or larger)
- 20+ small pins, brads, nails, paper clips, any tiny magnetic objects will do

Tools

- Small Hand Saw (to pre-cut the wooden blocks)
- Tape Measure



Procedure

1. ***Remove*** 1" of the insulating enamel from both ends of the two wires using the sandpaper or emery cloth.

2. Take the longer (12") length of copper wire and ***wrap*** it several times around the nail, leaving 4" of wire on each end. Take one end of the wire and ***bend*** it into a "j" shape.

3. Take the shorter (6") length of wire and ***bend*** one end into a "j" shape.

4. ***Fold*** the paperclip open so that it makes an "s" shape.

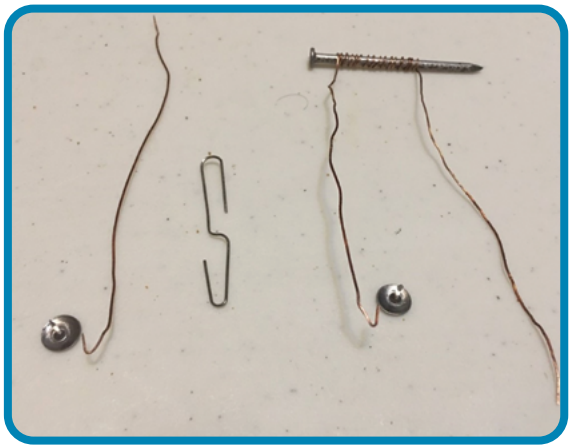
5. Secure the long wire and paperclip to the wood with a tack: hook both the "j" end of the nail's wire and the bottom loop of the paper clip "s" onto the pin part of a tack, then push the tack all the way into the wood block.

6. ***Bend*** the paper clip upwards slightly so that the free end is ½" above the wood.

7. Make the push switch: Take the "j" end of the short wire and ***hook*** it around the pin part of another thumb tack, then push the tack into the wood right below the free end of the paper clip. When you push down on the raised end of the paper clip, it should touch the tack below to close the circuit.

8. ***Attach*** one battery connector clip to the free end of the short wire.

9. Attach the other battery connector clip to the free end of the nail wire.



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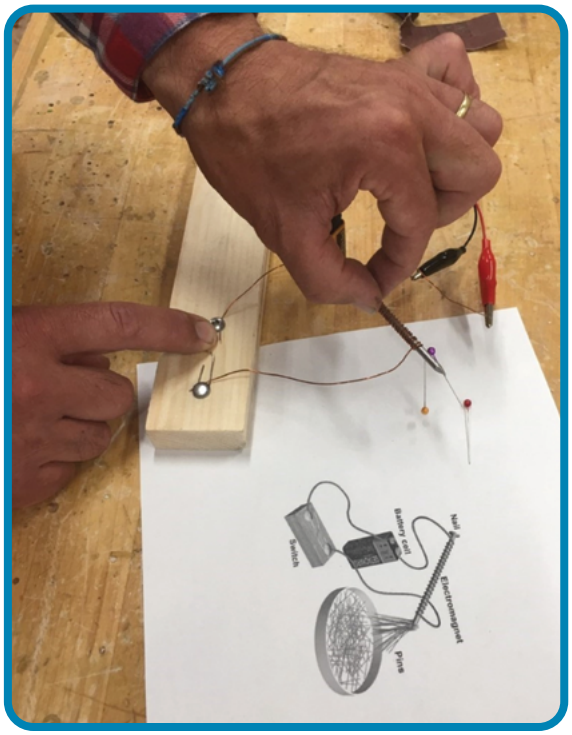

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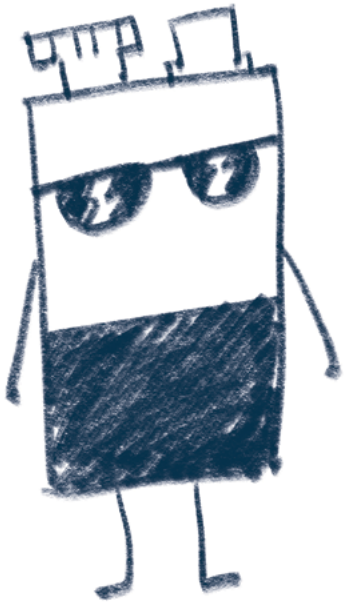
10. ***Connect*** the 9V battery to the connector.

11. Holding the nail with one hand, push down on the paper clip to close the circuit. Try picking up some pins or small nails with your electromagnet.



Troubleshooting

- Make sure that the alligator clips are making tight contact with the wires.
- Make sure you scrape all of the enamel coating off the last 1” of the wires, then make the connections to the bare copper.
- Follow the circuit path with your finger and make sure there are no breaks in the circuit, or short circuits (places where electricity flows in unintended paths, possibly where a wire is touching another part of the circuit where it shouldn’t be).
- Check the voltage of your battery with the multimeter; replace the battery if it reads less than 5.5 volts.
- If the magnet is too weak, try adding a few more wraps of wire to the nail.

Extension Challenges

- Design a scientific experiment to determine what variables make the electromagnet stronger: different nail size or material? Different wire type or number of wraps? Use the number of pins lifted as your dependent variable. Make a table to record your results in.

- How long does your nail (core) retain its magnetism? How many objects can you pick up with the circuit on? How many objects can you pick up with the circuit turned off? Can you still pick up as many objects after leaving the circuit off for 10 minutes? 20 minutes? Can you find a way to "demagnetize" the nail?

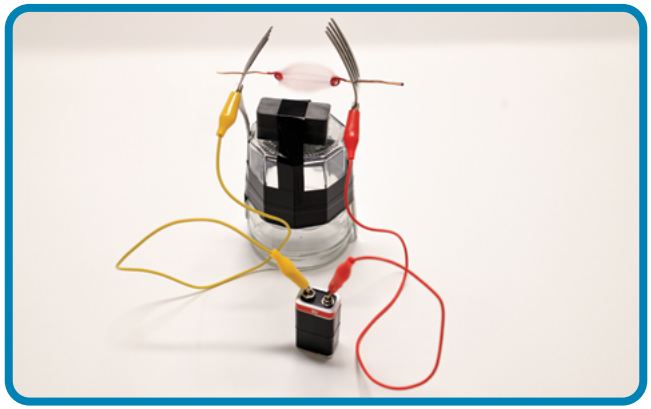
- Design and build a different type of "on/off" switch for your electromagnet circuit.

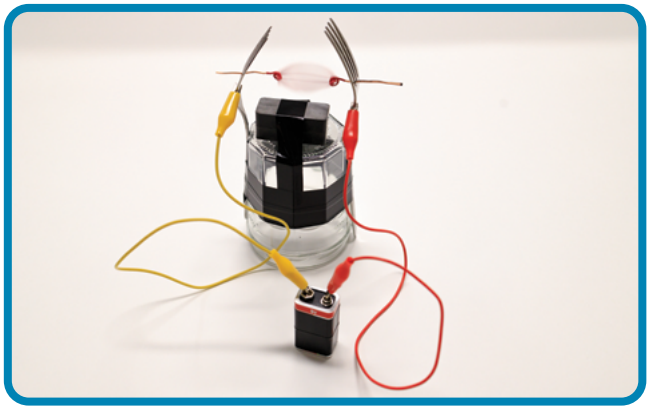
- Make a game or puzzle or magic trick that utilizes an electromagnet.

- Design an electromagnet apparatus with a clear plastic or glass tube that causes a metal object or magnet to levitate.

SIMPLE MOTOR

Electric motors are used every day in all sorts of trades jobs: from hand drills that glazers use to install window casings to kitchen blenders that bakers use to mix ingredients, to lathes, table saws, routers, starter motors, the list is endless. Practice coiling wire like a motor winder, then hook your coil up to a battery and watch how a magnet field transforms the electrical energy into kinetic energy, making your wire coil spin around!





Materials

- Two similarly sized metal forks (confirm their conductivity using a multimeter)
- Two connector wires with alligator clips
- 9V battery
- 1 (or more) strong magnets, any type
- 20” insulated wire, 18 gauge or similar
- A found object for a base to tape forks to, such as a mug or wood block (approx. 3” cube)
- Electrical tape or similar

Tools

- Wire strippers
- Pliers
- Found solid cylindrical object (approx. 1” diameter, such as a C battery or dowel)
- **Optional:** super glue, scissors

Procedure

1. Measure and cut 20” of wire.

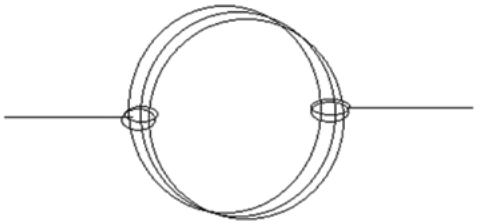
2. Wind the wire around the cylindrical object to create your coil. Pull the coil away and secure the ends at the 3 o’clock and 9 o’clock positions by bundling the coil with some wraps of the wire ends. Make sure to leave about 1-½” of wire extending from each side.

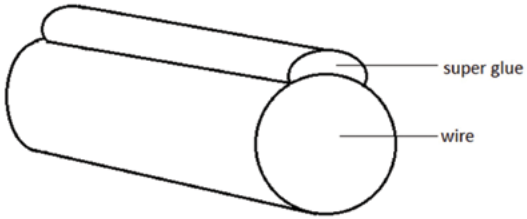
3. Use wire strippers to remove the insulation from both of the wire ends.

4. Next, you will need to create one small strip of insulative material on the top of ONE of the arms. The barrier can be achieved in one a few different ways:

   Option a: Carefully lay a stripe of super glue on the top of ONE of the arms like in the diagram.

   Option b: Lay a thin strip (~1/16” wide) of electrical tape down on the top of one of the wire arms, similar to the position of the super glue in the diagram.





5. Put the magnet on top of your base. Have a partner hold the forks, tines pointing up, on either side of the base.

6. Slide your coil onto the forks so the tines support the arms, and the coil sits between the forks. Have your partner lower the forks until the bottom of the coil is about ½” above the magnet, then tape the forks on.

7. **Make a circuit:** use the connector wires to connect one fork to the positive 9V terminal, and the other fork to the negative 9V terminal.

8. Give your coil a push to start it spinning; it should continue spinning on its own!

Troubleshooting

- Make sure that you use a fresh battery (you can check the voltage with your multimeter - if it reads less than 5.5V, try a new one).
- Check that the barrier strip (super glue or tape) is intact on the top of ONE wire arm, and that the other arm is completely bare. The insulation strip provides a barrier between the wire and the fork that stops the electrical current for a quick moment every time the coil spins around. This momentarily "turns off" the magnetism of the coil once every rotation and allows the motor to keep spinning (instead of getting stuck in the one position where it's most attracted to the permanent magnet).
- Ensure that the coil can spin freely and is well balanced - you may need to reposition the arms to make them stick straight out from 3 and 9o'clock.
- Try using a stronger magnet, or use a stack of magnets, or turn your magnet upside down.
- Bring your coil and magnet closer (slide your forks down or place an object under your magnet).

Extension Challenges

- Experiment to see what you can change about your motor design that makes it spin faster or slower.
- Make a tiny version of the motor using thinner wire, a smaller battery, and paper clips or safety pins instead of forks.
- What kinds of spinning motors can you recall from your daily life? (Think about electric devices in your kitchen, or in a wood shop...) Can you make an attachment to the end of your wire to get your motor to do something useful? For example, make a paper pin wheel and turn your motor into a fan! Or could you add an attachment that turns your motor into a winch by winding a thread up and lifting a paper clip off the floor?
- Find the RPM of your motor. Count the number of rotations for 15 seconds, then multiply by 4 (this gives you the number of times it rotates every 60 seconds, called "revolutions per minute")
- Can you make the motor coil spin the opposite way? How?

MAGIC MATCH BOX

Learn about circuits and switches to baffle and amaze your friends with a trick match box that only buzzes when YOU are holding it. Hold the magic match box in your hand and your secret magnet ring connects a circuit within the box to power a small mini motor that buzzes the box for you, but not for anyone else!

Materials

- 3V coin battery (CR2016 or similar)
- Vibrating mini motor disc (2-5 Volts DC)
- Steel ball bearing (or sling shot ball), about 6mm diameter
- Small neodymium magnet (about 6mm diameter)
- Conductive tape (aluminum duct tape or copper tape)
- Small match box
- 8” insulated copper wire or enamel wire, any gauge

Tools

- Scissors
- Needle nose pliers
- Wire cutters
- Clear tape and/or electrical tape
- Found cylinder, same diameter as your finger (e.g., highlighter pen)

Procedure

1. **Use scissors:** cut two 2” strips of conductive tape, about ¼” wide.

2. Open the matchbox. Peel the backing off the conductive tape strips and stick them into the matchbox as shown. Leave a 1/16” gap between them at the bottom corner so they don’t touch each other.

3. Stick the black motor wire to the conductive tape on the side of the box with clear or electrical tape.

4. Place the battery onto the bottom conductive tape as shown, positive side up. Lay the end of the red motor wire on top.

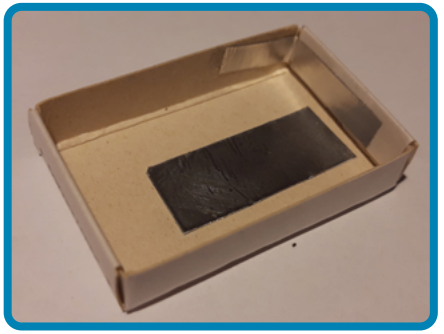
5. Use a piece of electrical tape to secure the wire and the battery to the bottom of the box. Leave the very end of the conductive tape bare like in the photo.

6. **Test your circuit:** push the ball bearing into the corner where the conductive tape strips meet. Your mini motor should start buzzing.

7. Leave the ball bearing in the box. Slide the cover back on to close it.

8. **Make the ring:** bend the wire twice around a cylinder the same size as your finger.

9. Use pliers to bend the ends around as in the photo to make a flat spot to place the magnet.



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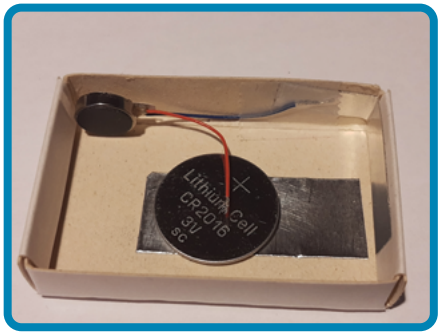

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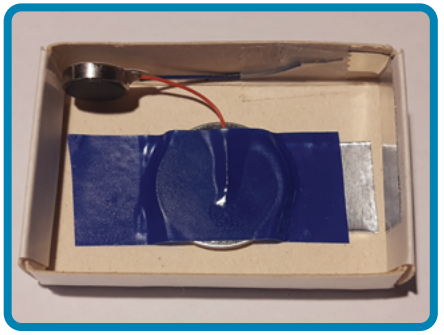

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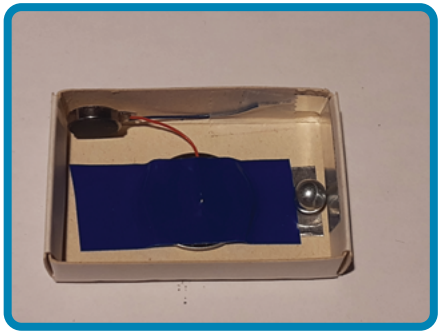

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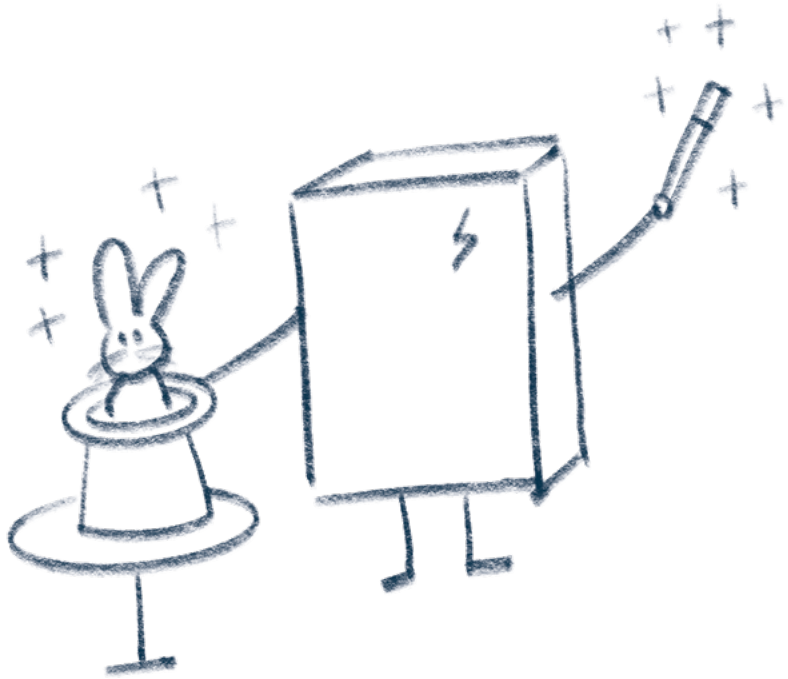
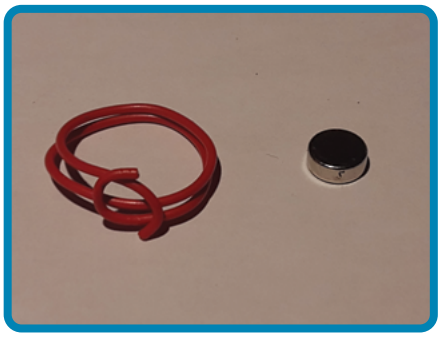
10. Place the magnet on the top of the flat spot like a jewel. Wrap a piece of electrical tape around the ring to secure the magnet in place.

11. Put the ring on so the magnet is hidden near your palm. Hold the box in your hand so the magnet pulls the ball bearing into the corner and turns the mini motor on.

12. Practice your magic trick! You could pretend there's a live bird in the box that only YOU know how to wake up... or maybe there's a cat purring inside? Challenge your friends to try and get the box to make noise, and then show them how "easy" it is when they can't seem to get it working.

13. **Note:** you might want to wrap a piece of tape around the matchbox ends if you don't want anyone to open it and learn the magic (or lose the ball bearing!).





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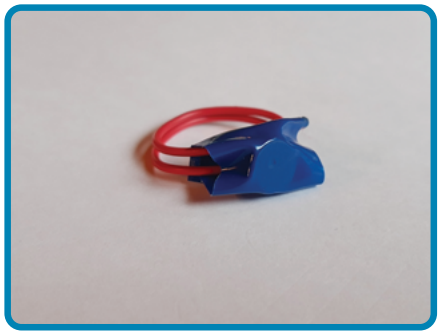

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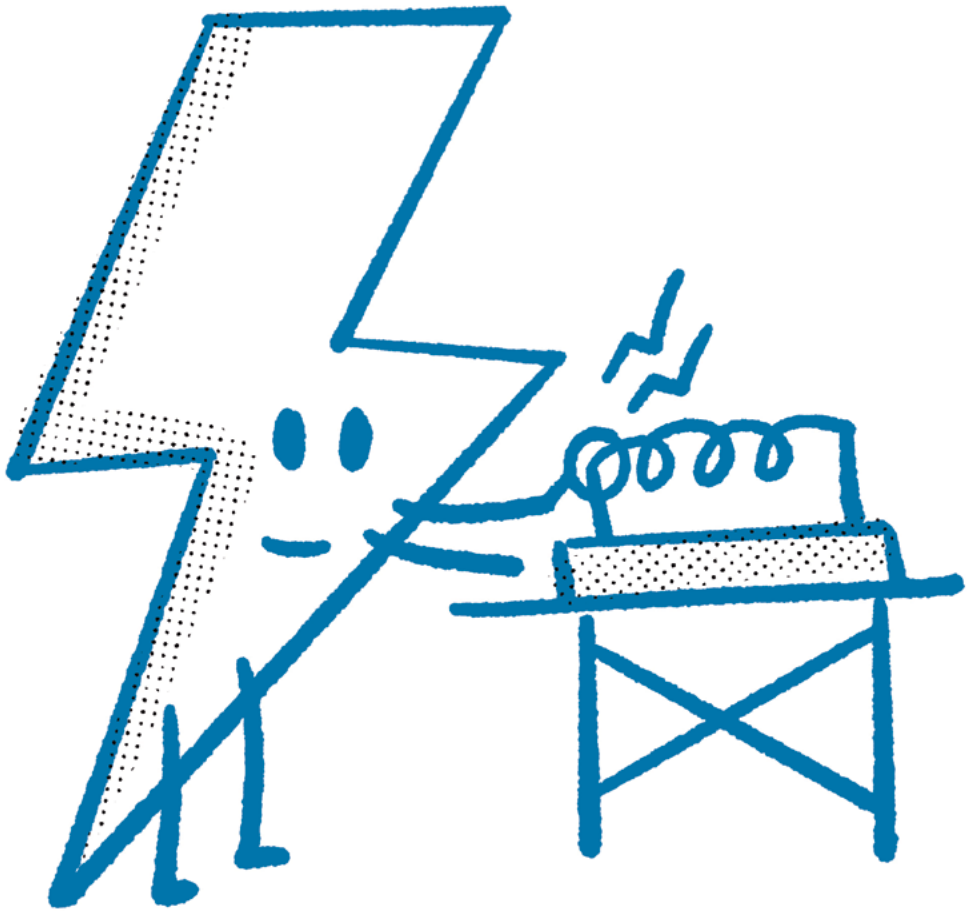
Troubleshooting

- Does your motor not buzz? Use a multimeter to check that your battery has at least 2V left, or start with a fresh battery.
- Try pressing down hard on all the tape to secure the connections with the motor wires.
- Is your motor buzzing constantly? Check that your conductive tape strips are not touching each other.

Extension Challenges

- What other switches can you make that utilize a magnet? Research how a “reed switch” works, then design a box that uses one to light up an LED when you bring a magnet close.
- Make a personal matchbox flashlight using this design.
- Embed your magnet in a fancy ring made of polymer clay if you want it to be really hidden.

FUN WITH ELECTRICITY



CAREER BITE

Lindsay Kearns

What trade are you working in, and can you briefly describe what kind of specialty role you have within that trade?

I am a Red Seal Construction Electrician, with a specialty in DDC, which stands for "direct digital control" (more commonly known as building automation).

What 5 tools do you use the most?

The 5 tools I use the most are:

a. Lenox 9-in-1 multi screwdriver
b. Wera slotted tip insulated screwdriver with 2.5 mm blade
c. Klein electrician's scissors
d. Klein high-leverage linesman side-cutting pliers
e. My log book, where I track all the details of my projects every day

How does your trade appear in people's everyday life?

I install and maintain sensors, relays, motors, and microcomputers that control the heating, cooling, and lighting in commercial and institutional buildings, from malls to museums to schools to government buildings such as the provincial legislature. If you've visited any building like that in the Greater Victoria area, chances are you've benefited from a system I've worked on!

How did you decide to pursue the trades?

I initially went to my local college for a 6-month entry level training course in electrical, because though I didn't know much

about the trades, it seemed like a good way to earn a decent wage while I decided what to do with my life. I quickly realized that this was the work I wanted to do: I love problem solving, creating order, and making things happen!

What is one piece of advice you'd want to give your past self and/or someone wondering if a career in your trade might be for them?

Learn how to communicate clearly and effectively. While there's a lot of technical knowledge required in my trade, there are also many problems that can be fixed or prevented by taking notes, asking questions, and talking with all the other people that make a project successful, including other trades, contractors, engineers, etc. Cooperation and respect are key to a job well done, and make the work days much more enjoyable.

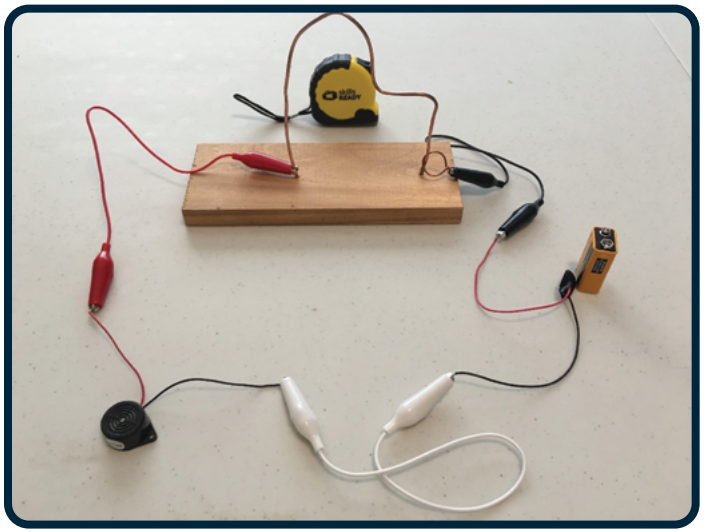
WIRE LOOP BUZZER GAME

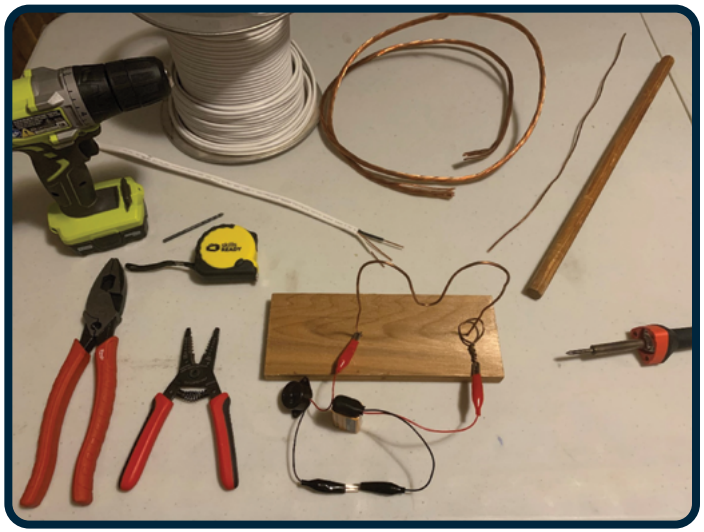
This project helps students learn the fundamental elements of an electrical circuit through creating an interactive wire loop buzzer game. As the students go through the different steps in assembling the game, they gain familiarity with common electrical hand tools.

The game involves guiding a metal loop along a serpentine length of wire without touching the loop to the wire. The loop and wire are connected to a power source and a buzzer such that, if they touch, they form a closed electric circuit and set off the buzzer.

Bare copper wire can be used to make this project (pre-stripped and pre-cut for novice makers), or you can practice using wire strippers to remove the insulation from common electrical wires: use 12-gauge solid ground wire to get your 16” piece, and use a length of 14/2 electrical wire to get your 4” piece. See procedure steps for more details.

See our “Make Your Own Connector Wires” project to make the wires for your wire loop buzzer game!



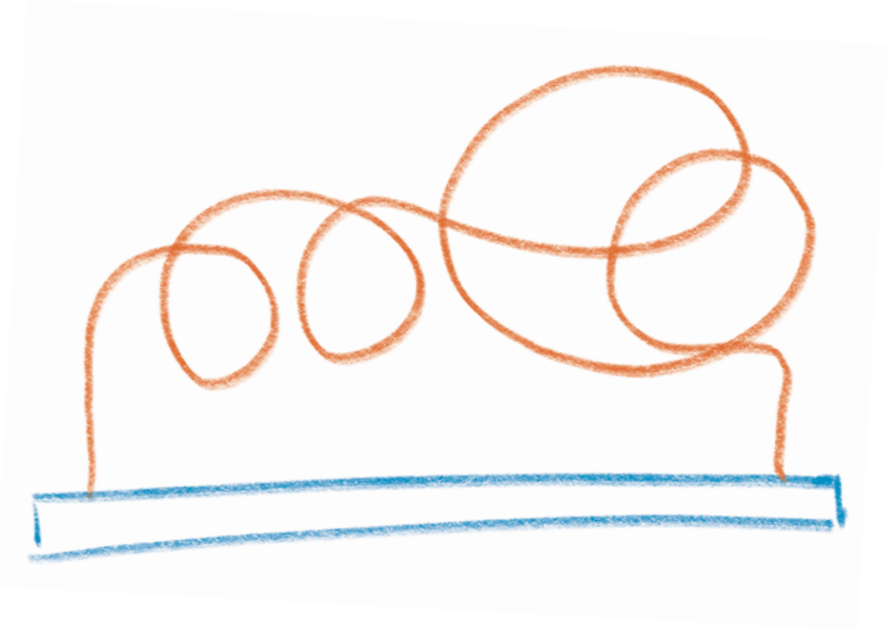


Materials

- One piece of 1″ x 4″ x 8″ Common Fir or similar softwood
- One 4″ length of ¾″ dowel, or any tube-shaped object (e.g., glue stick) of similar diameter
- One 16″ piece of 12-gauge solid copper wire (take from ground wire)
- One 4″ piece of 14-gauge solid copper wire (take from 14/2 Electrical wire)
- Three connector wires with alligator clip ends
- 9V battery
- 9V Battery clip
- Active buzzer
- **Optional:** fine electrical solder
- **Optional:** five alligator clips

Tools

- Small hand saw
- Tape measure
- Cordless drill
- 1/8″ drill bit
- Linesman pliers
- Wire stripper
- **Optional:** Utility knife
- Soldering iron



Procedure

1. ***Measure and Cut*** an 8” length of 1x4. This will be the base.

2. ***Measure and Mark*** the location for two holes to mount each end of the thicker electrical wire. Holes should be 4” to 6” apart.

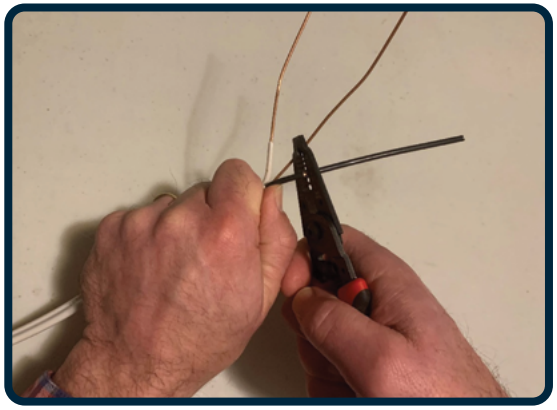
3. ***Drill*** two holes to a depth of ½”.

4. If you are starting with insulated 12-gauge ground wire, put the wire into the slot on the wire strippers marked “16”. Squeeze the handles together to cut through the insulation. Pull on the insulated end of the wire with one hand while keeping the strippers closed with the other. This will separate (strip) with insulation from the wire. Strip until you have 16” of bare copper exposed, then cut this 16” away with the blades on the wire strippers.

5. ***Bend*** the 16” piece of 12-gauge wire into a fun or tricky shape and fit the ends into the holes you drilled in the wood.

6. The 14/2 wire (which is commonly used in residential wiring) consists of three strands of solid 14-gauge copper wire, two of which are insulated. The three wires are enclosed in an outer layer of insulation. Using the blade on the wire strippers or a utility knife, carefully cut open the outer layer of insulation and peel it back about 6”. Put one of the insulated internal wires into the slot on the wire strippers marked “14” and strip 4” of insulation away.

7. ***Cut*** a length of the 14-gauge wire at least 4” in length using the blade on the wire strippers or on the Linesman Pliers.



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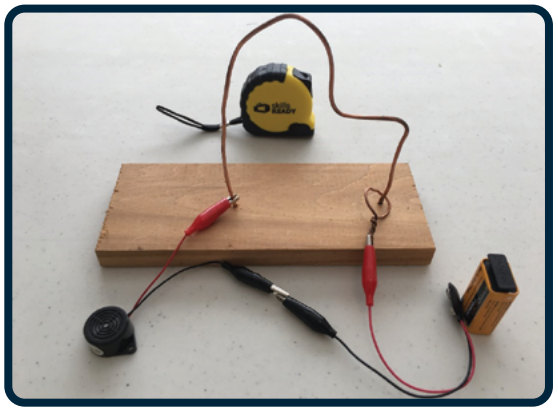
8. ***Make*** a loop in the 4" piece of wire using the dowel (or similarly sized object) to form a circle. Use the Linesman Pliers to ***twist*** the ends of the wire into a single strand.

9. ***Slip*** the copper loop off the dowel, lift one end of the 12 gauge wire out of its hole, put the loop around the hole and re-insert the heavy wire.

10. Connect one buzzer lead to one side of the 12-gauge wire with one connector wire. Connect the other buzzer lead to one of the battery leads with a second connector wire.

11. Connect the second battery lead to the 14-gauge wire loop with a third connector wire. Your game is ready to be played!

12. **Optional**: If time and ability allows solder alligator clips to the ends of the leads on the battery clip and buzzer as shown.



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Extension Challenges

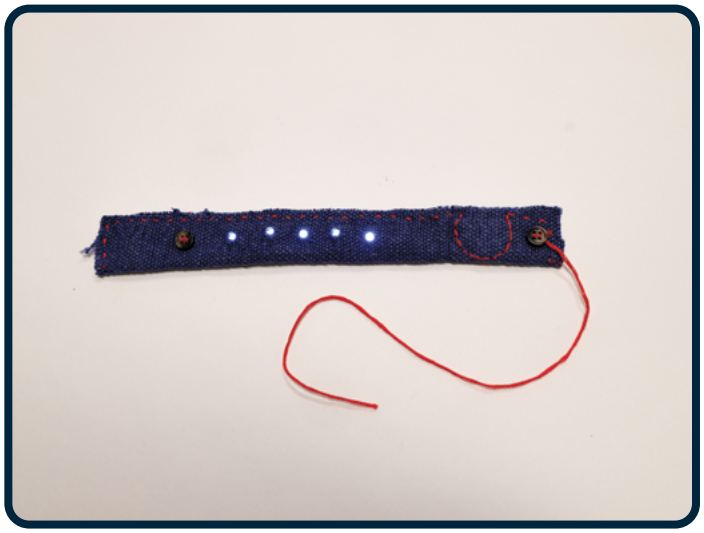
- Make your own connector wires to use in this project.
- Insert a vibrating motor into the circuit in the handle of the wire loop to provide tactile feedback.
- Insert LEDs or some deconstructed holiday lights into your circuit to provide visual feedback.

BRIGHT BRACELET

This project shows you how to make a light-up bracelet using tiny LED bulbs, conductive thread, and a coin battery. Some basic sewing skills or experience will be helpful while you sew your circuit into the fabric, as keeping your sewn circuit tidy will prevent any short circuits.

Make sure you store your bracelet somewhere safely out of reach of small children and pets, as the coin batteries are harmful if swallowed.

This is a great project to help grade 7 science students visualize batteries as a source of electricity, brainstorm other applications for lightweight batteries, discuss or explore the environmental impacts of battery production and disposal, as well brainstorm or look up alternate ways to power LEDs. It can also be a fun way to introduce the differences between series vs parallel circuits, as the LEDs are all sewn in parallel in this design.



Materials

- One 3V coin battery (CR2016 or similar)
- Five 3mm LED bulbs (any colour)
- 3’ stainless conductive thread
- ~2 ½” x 8” sturdy scrap fabric (e.g., denim or canvas)
- 3’ regular thread
- Two small buttons
- 1’ light string or embroidery thread

Tools

- Measuring tape or ruler
- Black felt pen
- Needle nose pliers
- Large sewing needle
- Scissors
- Pencil
- **Optional:** hot glue gun

Process

1. Prepare your LEDs for sewing -- splay the LED wires apart and use the felt pen to colour the LONG wire of each LED black.

2. Use the needle nose pliers to curl each of the LED's wires as shown.

3. Layout the bracelet circuit: Before you go to step 4, examine the diagram for this step. This is what the INSIDE of your bracelet will look like before you fold it in half. The LEDs are lined up on the bottom half of the fabric with the black (long) wires pointing DOWN. The coin battery will be sandwiched between the two circles on the right when you fold the fabric in half. The black stitches represent the stainless conductive thread: one thread connecting the positive side of the battery to all the black LED wires, the other conductive thread connecting the negative side of the battery to all the short (uncoloured) LED wires. Refer back to this diagram as you position your LEDs and sew your conductive thread lines.

4. Use the felt pen to trace the two battery-sized circles on your fabric, and five dots for LEDs, just like in the picture in step 3. Label the top circle with a "-" for negative, and the bottom circle with a "+" for positive.

5. Use a pencil to poke tiny holes in the fabric at the LED dots, then push an LED bulb into each hole.

6. Twist your LEDs until all the black (long) wire loops are pointing straight DOWN, like in the diagram in step 3. Fold your bracelet in half to check that the bulbs are poking out through the middle of the bracelet as in the photo.

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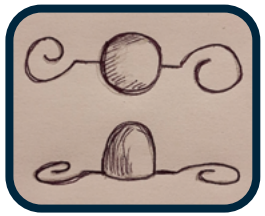

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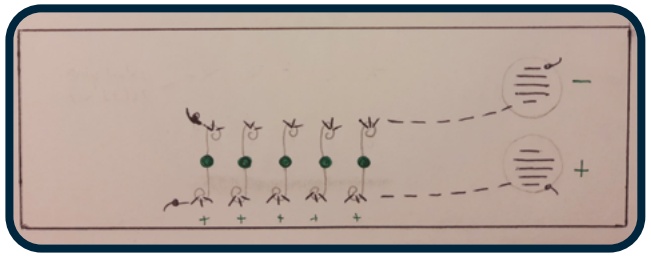

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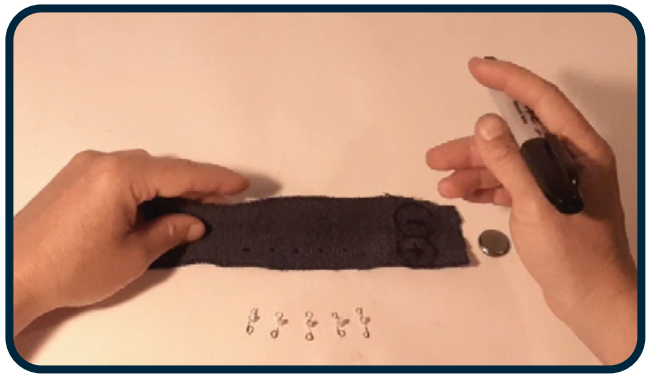

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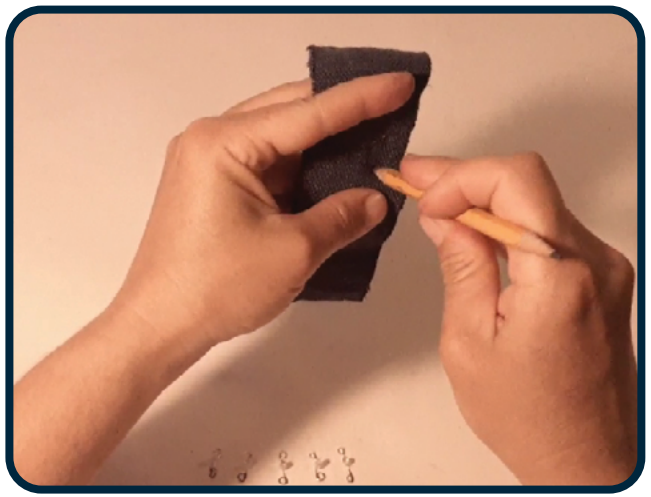

7. Sew the stainless conductive thread circuit: Sew the POSITIVE side of your circuit: use one 1 1/2' piece of conductive thread. Start by securing the thread with a knot, then sewing a few long stitches into the bottom "+" circle, then stitch a line towards the lower black LED wires. When your stitches reach the LEDs, stitch the BLACK wire of each LED onto the fabric as shown, using three tight stitches wrapped around each wire. Tie a knot in the conductive thread and cut the tail end short.

8. Repeat steps 6 and 7 to sew the NEGATIVE side of your circuit, securing the unmarked (upper) LED wires onto the fabric.

9. **Optional step:** if you are concerned about short circuits in the section of sewing between the battery and the LEDs, you can run a line of hot glue along these stitch lines to insulate them electrically. Make sure not to get glue on the stitches in the CIRCLES, as this will prevent the thread from connecting to the battery.

10. Fold your bracelet in half lengthwise, flipping the bottom up to meet the top edge so you can see your LED bulbs poking through the fabric. Place a coin battery between the two circles to test your circuit. Does it light up? If yes, move on to the next step. If no, try flipping it around, or refer to the troubleshooting steps at the end of this project.

11. Plain thread stitching: (use the diagram in step 11 as you work through to step 15). Use plain thread to sew a tight "U" shape around the battery, as in the diagram. Stitch closely to the battery so it fits snugly, but so that you can still push it out of the pocket to turn it off. (Also, because LEDs only work when the electricity flows in one direction, you can flip the battery

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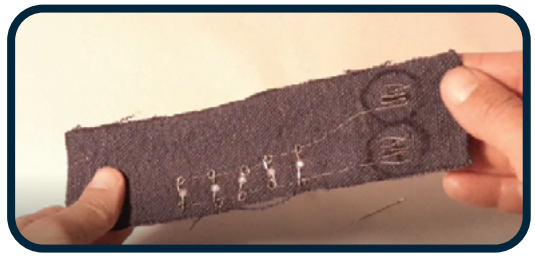

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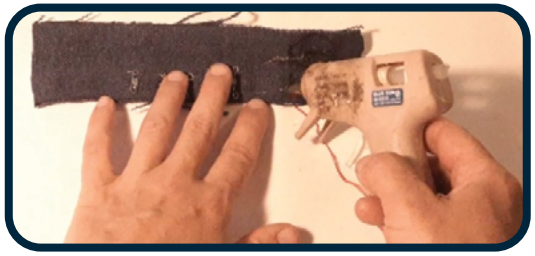

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BACKWARDS in the pocket when you're not wearing it to store it in the off position).

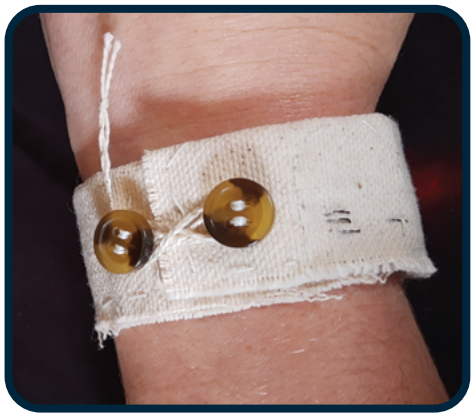
12. Use plain thread to sew up the edges, leaving the battery pocket edge open (see the photo for step 12, as well as the diagram in step 11).

13. Make the closure mechanism: use plain thread to sew one button on next to the battery pocket.

14. Tie one end of the embroidery thread to the button or sew it onto the end of the bracelet. Tie a knot in the other end so it doesn't fray.

15. Sew the second button on (see the picture in step 14). The distance between the two buttons should be the diameter of your wrist; use your measuring tape to confirm this measurement.

16. Put the bracelet on and secure by winding the embroidery thread in figure 8s around the two buttons. Enjoy!



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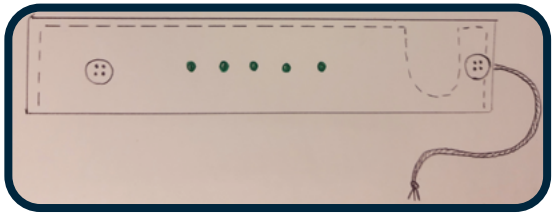

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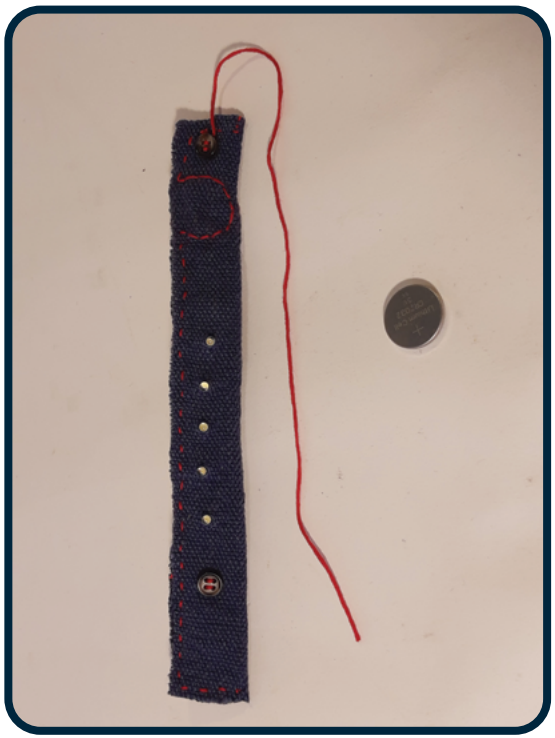

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Troubleshooting

- Make sure that you start with a fresh battery (you can check the voltage with your multimeter).
- Keep in mind that when you sew with conductive thread, you are making a circuit. Your LEDs must be sewn in "parallel", like a ladder: side rails made of thread, and the LEDs forming the rungs in between. If any part of the left rail of your ladder touches the right rail, you will get a short circuit, and the LEDs won't light up properly. One way to prevent a short circuit if you've sewn one side too close to another is to coat the inside conductive stitches with dots of hot glue before folding the bracelet in half.
- Do only some of your LEDs light up? You may have sewn them in backwards. Start again, making sure you colour each LED's long wire black so you can keep track of them. Sew all of the black wires together with one piece of conductive thread, and all of the plain wires together with a separate piece of conductive thread.
- Does your battery fall out? Put another "U" of regular thread stitching around it to hold it in more tightly, make a flap to hold it in place, or use a coin battery holder made for sewing projects.

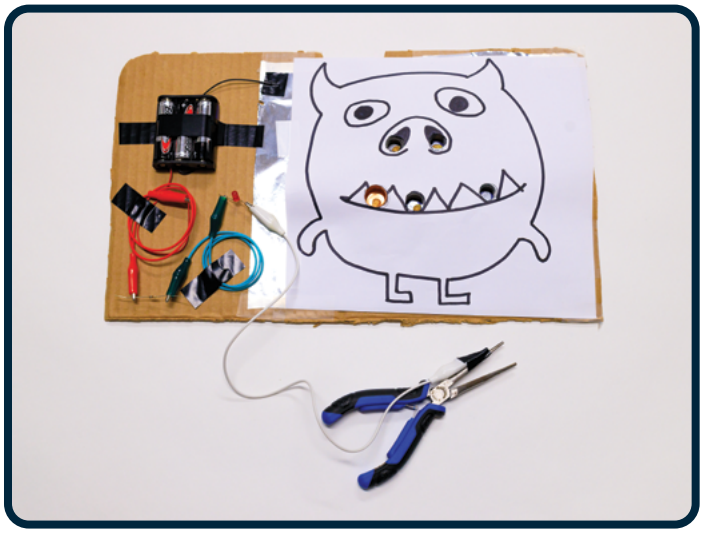
Extension Challenges

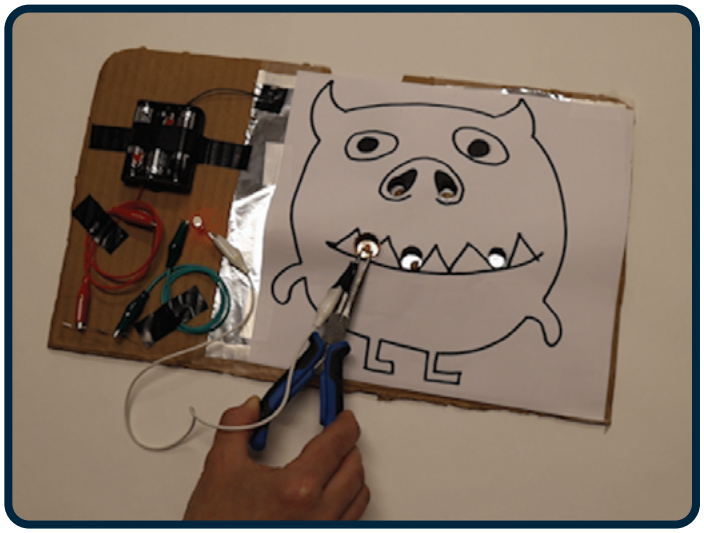
- Use a different closure mechanism of your choice to secure the bracelet on your wrist.
- Use the circuit-sewing skills you learned in this project to add LEDs to a toque, jacket, headband, or whatever wearable item you choose.
- Add LEDs to a patterned T-shirt to add detail and highlights (e.g., light-up eyes, headlights, whatever on the design might need a light).
- Search "etextiles" on the internet for more ideas!

PICK THE BOOGER

The “Pick the Booger” project shows you how to make a customizable game of skill that will not only help you get better at using needle nose pliers, but also let you experiment and play with simple electrical circuits. When you fumble and the pliers make a connection with the game board, the electrical circuit is completed and your board lights up! The game is a great way to visualize how a break in a circuit prevents electricity from flowing, as well as illustrate how one might unintentionally complete a circuit with a metal tool.

Design your own unique face plate to personalize your version of the game!





Materials

- One sheet of blank 8 ½" x 11" printer paper
- ~8"x11" aluminum foil
- ~8"x15" corrugated cardboard
- One 3mm or 5mm LED (3mm used in this example)
- One resistor rated for the LED being used (180 Ω used in this example)
- Three AA batteries
- One 3xAA battery holder (wire leads attached)
- Three connector wires with alligator clip ends
- One pair of needle nose pliers (to be incorporated into the project)
- Five+ assorted large metal nuts or copper end caps, inner diameters between ½" to 1"
- Five+ small non-conductive objects, such as un-popped popcorn kernels, beans, etc.
- Clear tape
- Electrical tape
- **Optional:** one vibrating mini motor disc (2-5V DC)

Tools

- Scissors or utility knife
- Pencil
- Felt pen
- Pencil crayons, felts, paints, etc. to decorate the game drawing

Process

1. Design the theme of your game. The purpose will be to use needle nose pliers to pick tiny objects out of the center of the nuts (and/or end caps) without letting the pliers touch the metal. You will be drawing an overlaying picture complete with holes to pick the objects from. Will you be picking stones out from shoe treads? Will you be picking boogers from an ogre's nostrils? Will you be plucking berries from a berry bush? Will you be picking the tastiest chocolate chips out of a bowl of trail mix? Once you know your theme, assemble your tools and materials for the next step.

2. On the blank paper, draw your picture outlines in pencil, then in felt pen.

3. Decide where on your picture your holes will be. Place a nut over each spot and trace around the inner diameter with a pencil.

4. Use scissors or a utility knife to cut the circles from your drawing.

5. Tape your aluminum foil flat to the cardboard with clear tape, leaving about 4" of bare cardboard on one end.

6. Place your drawing on top of the foil. Using the holes as a stencil, take the felt pen and draw the circles lightly onto the foil below. Lift the drawing off the foil.

7. If you want to, now is the time to decorate your drawing with pencil crayons, felts, paints, or whatever materials you choose.

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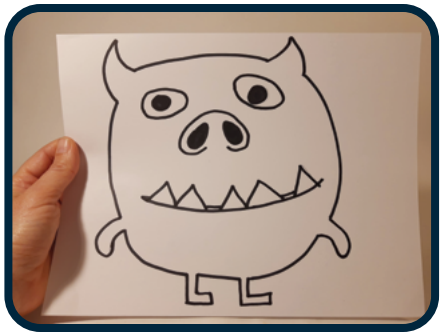

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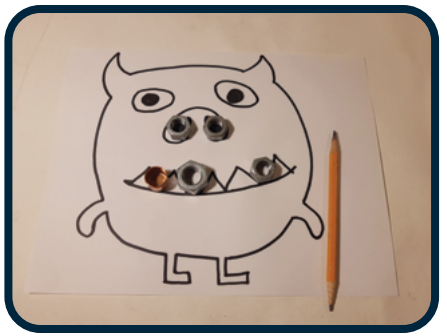

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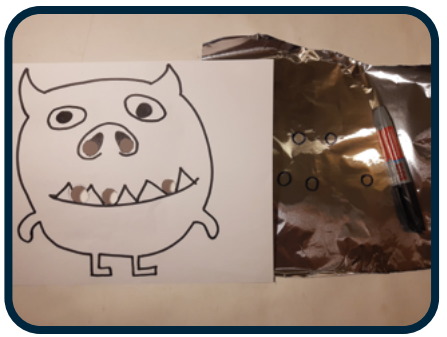


8. Place a nut over each circle on the aluminum foil. Use small pieces of clear tape to secure the nuts/endcaps in place, leaving the holes and tops of the nuts/endcaps uncovered.

9. Align the drawing on top of the nuts/end caps; you should be able to see down each hole to the threads of the nuts and the aluminum foil at the bottom. Tape around the edges of the paper with clear tape to secure it to the cardboard.

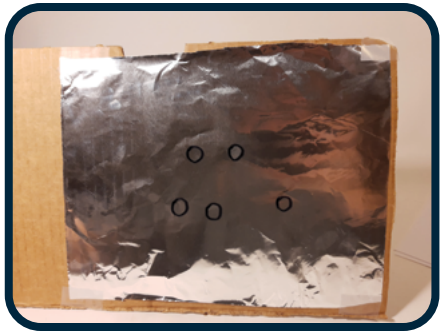
10. Make your circuit: use a small piece of electrical tape to secure the bare copper end of the BLACK wire from the battery pack to the aluminum foil. Press hard to make sure the copper and aluminum make good contact.

11. Use a long strip of electrical tape to tape the battery pack to the cardboard.

12. Clip a connector wire (red in the picture) from the red wire of the battery holder to one end of the resistor. Coil up the extra wire and tape it to the cardboard to keep it tidy.

13. Take a second connector wire (green in the picture) and clip one end to the free end of the resistor, and the other end to the positive (long) LED wire. Again, coil it up and tape it to the cardboard.

14. Use one more connector wire (white in the picture): clip one end to the negative (short) LED wire and use electrical tape to secure the connector wire's other alligator clip to a metal part of the needle nose pliers.



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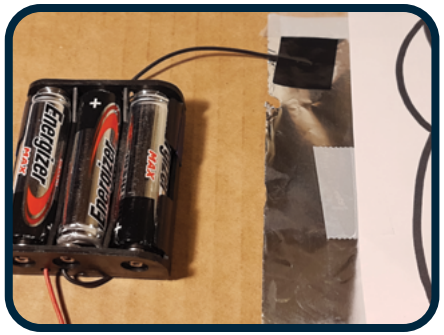

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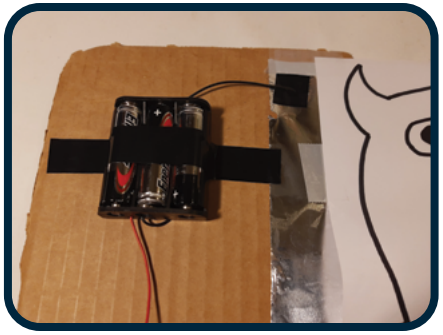

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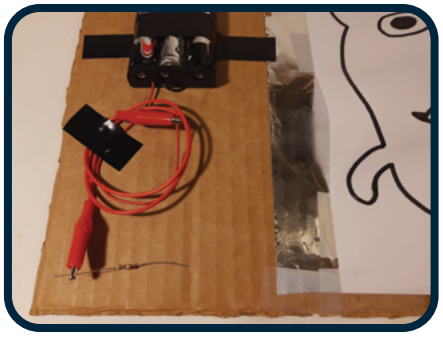

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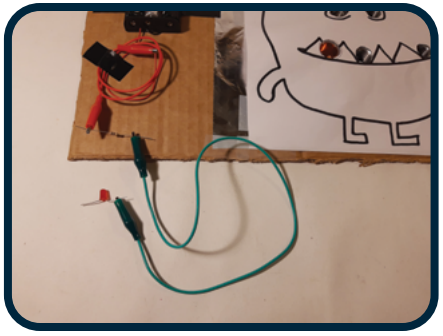

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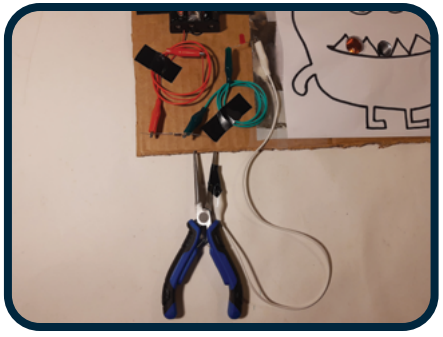

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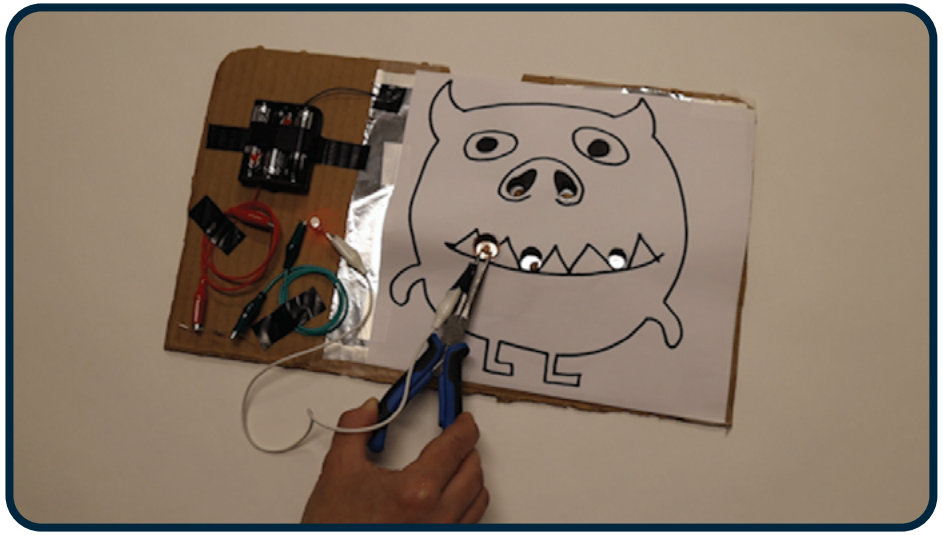
15. Test your game by connecting the circuit: touch the needle nose pliers to each of the nuts, and to the aluminum foil at the bottom of each hole. The LED should light up each time you connect the circuit.

16. Drop one of the small non-conductive objects into each hole and practice picking them out without turning the LED on. Challenge your friends to play your new game! See who can pick all the items out the fastest, or with the least LED flashes.



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Troubleshooting

- Make sure that each nut is taped down to the aluminum foil securely to ensure a solid electrical connection.
- Check for possible short circuits: make sure that the only metal bits touching the aluminum foil are the end of the black wire from the battery, and the nuts under your picture. Insulate any other metal, such as the alligator clip ends, with a wrap of electrical tape if they keep accidentally touching each other or the foil.
- Is your LED wired in backwards? Unclip it from the connector wires, turn it 180° and clip it back in place.
- Did you accidentally touch connect the LED without having the resistor in the circuit? Too much voltage and current can burn out an LED – try a new LED if yours won't light up in either orientation.
- Is the connection between the pliers and the alligator clip solid? Tighten and add more tape if necessary.
- Do you need new batteries?

Extension Challenges

- Insert a tiny vibrating disc motor, gear motor, or hobby motor, into your circuit to provide touch feedback (make sure that they are rated for ~4.5V). Use electrical tape to secure the bare copper end of the black motor wire down onto a bare patch of metal on the pliers. Attach the motor's red wire to the connector wire leading from the LED. The mini motor will vibrate the pliers if you accidentally connect the circuit while picking out the object.
- Add an "active" buzzer to the circuit (in the same way as you would wire in the motor above) so you hear a beep as feedback when your pliers complete the circuit.
- Wire each nut with its own LED alert light. Experiment to find out which LED wire you must tape where to make this work. Where will you need to add resistor(s)?

FLASHY FLOUNDER

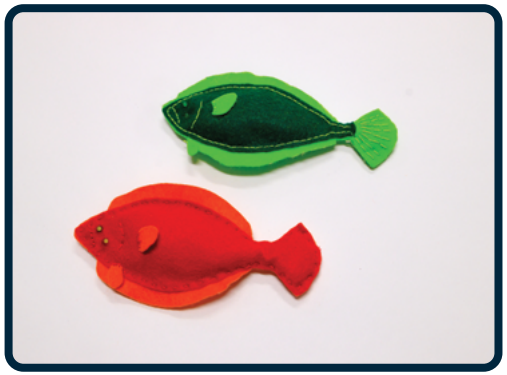
Make a light-up stuffy bottom-fish using some small LEDs and a hand-made squeeze button in the tail. Electrically conductive stainless thread allows you to SEW circuits into textiles, helping you visualize how to make a continuous, unbroken conductive path for the electricity, and troubleshoot any short circuit issues. Click the “download project” button on our project’s website for a pdf template to help you cut your fabric shapes.

Some previous experience with simple sewing techniques will help make this project a success. For beginners, instructors may want to consider printing the downloadable template onto cardstock and have makers sew the circuit onto one paper layer instead of the fabric, even using pre-punched holes to assist with stitching.

Be sure to keep coin batteries out of reach of pets and babies, as they can be poisonous when swallowed.

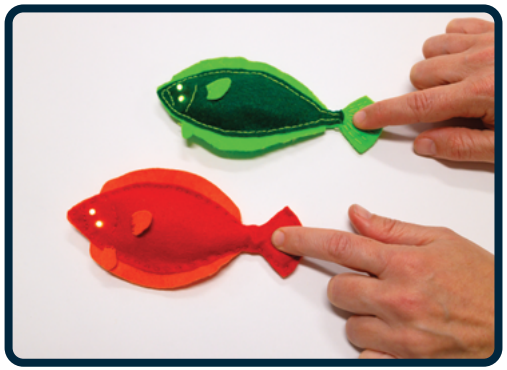
Materials

- Template print-out (full page - note the scale)
- Two sheets of felt fabric, different colours
- 3’ stainless conductive thread
- 3’ embroidery thread, colour of your choice
- One 3v Lithium coin battery (CR2016 or similar)
- Two 3mm LEDs in colour of your choice
- ~6 cotton balls



Tools

- Black felt pen
- Scissors
- Needle nose pliers
- Needle
- Pencil
- **Optional:** hot glue gun



Procedure

1. Use scissors to cut out the 8 shapes from the printed paper template.

2. Trace the paper shapes onto the felt with your felt pen, tracing the “bottom” and “fins” onto one colour of felt, and the “top” shape in different colour. The “squeeze switch” pieces will be hidden and can be made of any colour.

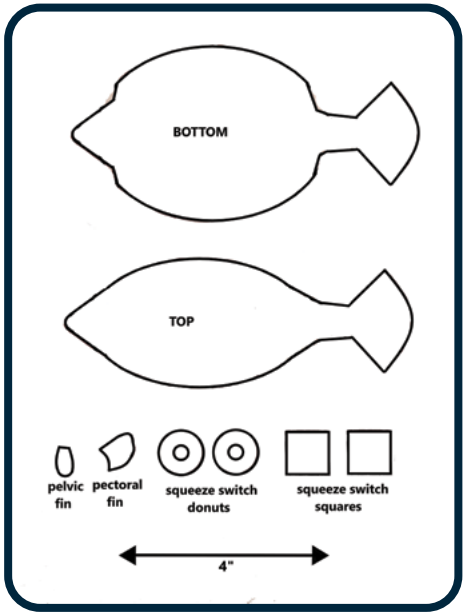
3. Cut the 8 felt shapes out with your scissors (TOP, BOTTOM, 2 squares, 2 donuts, 2 fins).

4. Test your LEDs by fitting them onto the coin battery as shown. If they don’t light up, flip the battery, and try again. Only move to step 5 when you have determined that the LEDs work properly.

5. Use black felt pen to colour each of the long LED wires BLACK. Leave the short wires plain.

6. Use pliers: bend and curl the LED wires as in the photo.

7. Cut a 1 ½’ long piece of conductive thread, tie a knot in one end and thread your needle onto the other end. Sew everything in this step without cutting the thread. Copy the sewing line in the diagram: on the “BOTTOM” felt piece, sew the BLACK LED wires down with 3 tight stitches on each wire loop. Sew in a line to the tail base, then make several big, long hashtag stitches on one square felt piece. Finish with a knot on the square piece, then cut the thread end short.



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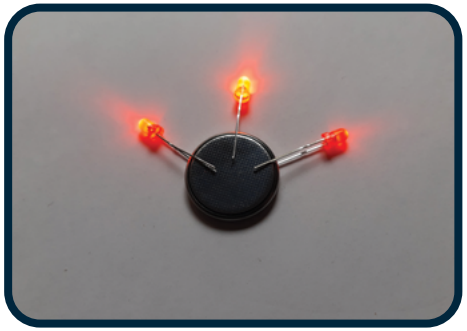
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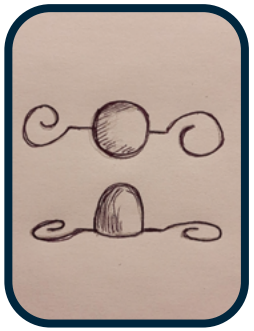
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8. Use a new 1 ½' piece of conductive thread to sew the second part of your circuit. Keep all your stitches at least ¼" away from the stitches from step 7; if they touch, you will create a short circuit and your LEDs won't light up. Sew the plain LED wires on with three tight stitches on each wire loop, then sew in a line towards the tail. Make big hashtag stitches on the other square. Finish with a knot, and cut the thread end short.

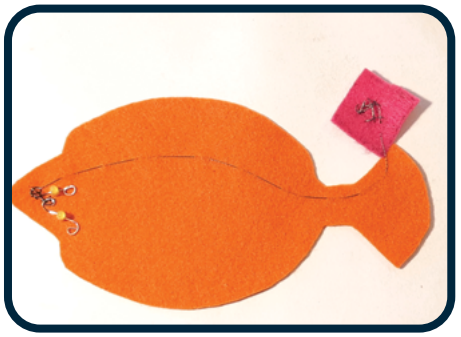
9. **Optional:** run a line of hot glue along your conductive stitching lines to electrically insulate them, preventing any short circuits.

10. Stack the felt donuts and battery between the squares as shown (square, donut, battery, donut, square). Arrange the squares so that the conductive threads poke out opposites sides, so they don't touch. Squeeze: if the lights don't work, see the troubleshooting advice below to get them working before you move on to step 11.

11. Use embroidery thread to sew the rest of the project. Stitch around the edge of the squares. Trap the battery and felt donuts inside.

12. Sew the fins on the TOP piece as shown in the diagram.

13. Line up the top piece over the bottom piece. Use a pencil: feel for the LEDs below and mark their position on the top piece of felt. Next, poke the pencil through the fabric to make eye holes for the LEDs to protrude up through.



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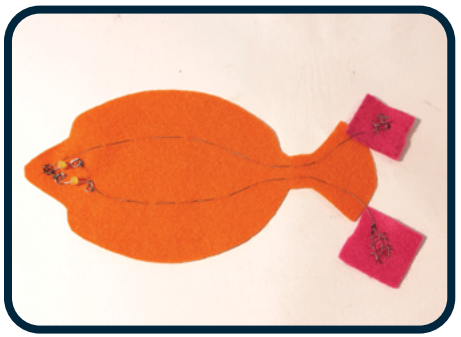

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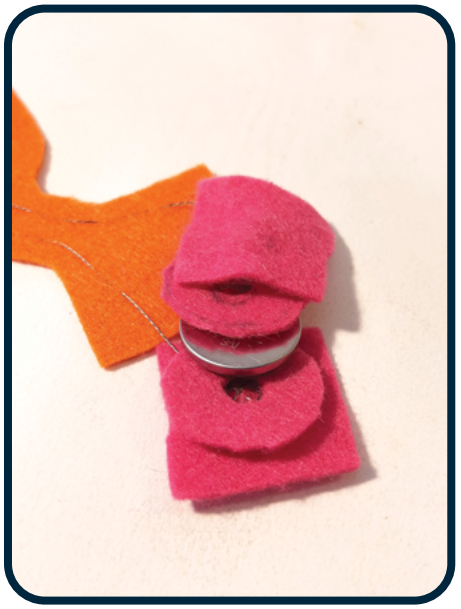

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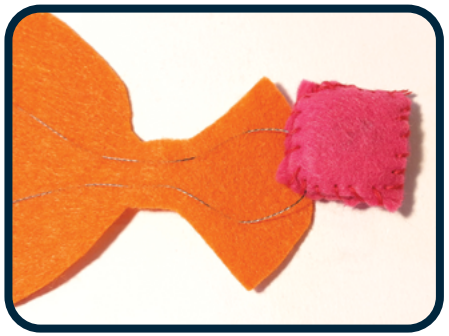

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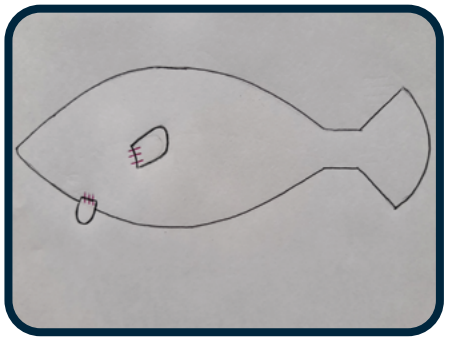

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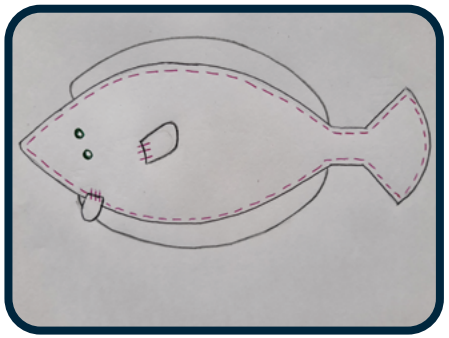

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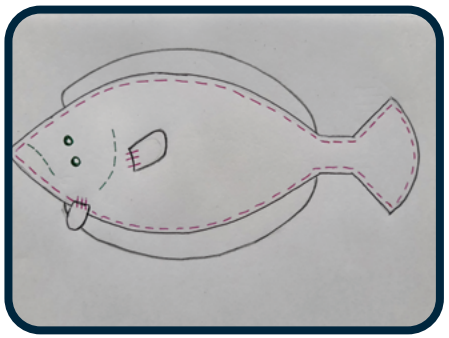

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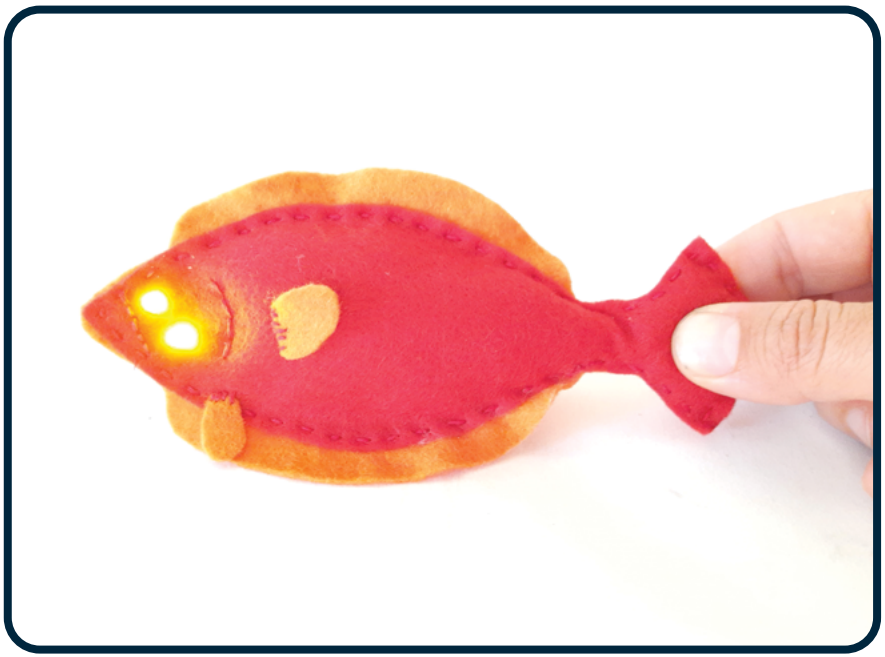
14. Use embroidery thread to sew the TOP felt piece to the BOTTOM piece along the lines in the diagram, trapping the square in the tail. Start your stitching near the top of the fish. Before you sew it closed, stuff the fish with some cotton balls, then finish your stitching line.

15. Sew mouth and gill lines as in the diagram. If you need to, you can sew "eyelashes" through all the layers to keep the top and bottom layers close, keeping the LEDs visible.

16. Enjoy your new light-up buddy!



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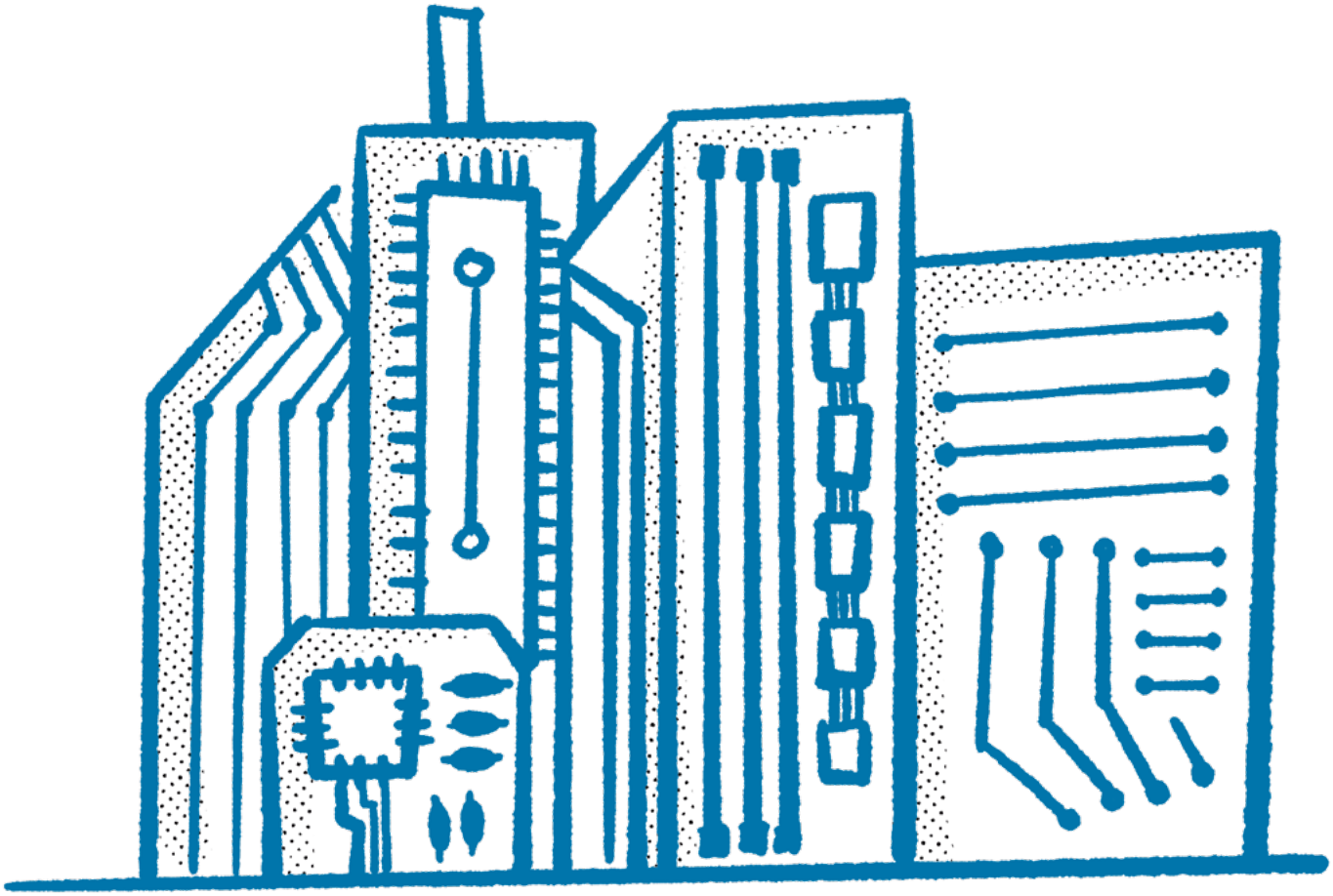
Troubleshooting

- Make sure that you use a fresh battery (you can check the voltage with your multimeter).
- Try flipping the battery around.
- Check that the positive and negative conductive threads aren't touching at any point in your sewn circuit. You can insulate your stitches with dots of hot glue to keep them from touching, if necessary.
- Line the holes of the donuts up carefully – the big hashtag stitching needs to be able to make contact with the battery terminals.
- Does only one LED light up? It's possible that the one LED was sewn in backwards. Pull out all your conductive stitching and try again, making sure you mark each LED's positive (long) wire black with felt pen, so you sew them both together with the same conductive thread.
- Test both LEDs with your multimeter on its continuity setting to make sure they still work.

Extension Challenges

- Use what you learned in this project to design your own LED light-up stuffy: you could use red, yellow, and green LEDs for a traffic light stuffy, make a stuffy boat model and give it red and green navigation lights, sew a red light-up heart patch on the chest of a bunny; have fun coming up with your own ideas! Make sure to sew your lights in "parallel": one continuous conductive thread should connect all the positive (long) LED wires to the positive side of the battery, and a second continuous conductive thread should connect all the negative (short) LED wires to the negative side of the battery.
- Make a whole of other light-up ocean-themed felt creatures.
- Using the squeeze-switch design, add LEDs and a battery to light up a toque or t-shirt.

CIRCUIT CITY



CAREER BITE

Cassidy Venoit

Cassidy Venoit is an apprentice construction electrician working in Victoria, B.C.

What trade are you working in?

I'm in electrical, and my last job was mostly a lighting job. I was putting the last finishing touches on a commercial site, putting up the lights and doing the wiring. Electrical has such a wide spectrum of different types of jobs you can do; there really is something in there for everyone.

What 5 tools do you use the most?

Cordless drill and impact driver
Crescent wrench or 9/16" wrench
Linesman pliers
Tape measure
Wire strippers

How does your trade appear in people's everyday life?

To put it simply, we're the ones who make the lights turn on! Electrical trades are in your lighting, heat, phones, tv, computer, everything electronic in your everyday life.

How did you decide to pursue the trades?

I was working in the IBEW (International Brotherhood of Electrical Workers labour union) office, helping out the admin assistants there, and one of the guys there said, "You know, we're doing this WATT program, and you've got nothing to lose, you've only got so much to gain. You don't have to pay to take the course, why not? Worse comes to worst, you have your ticket in electrical, and you can use that anywhere!" The WATT program provided me with all the basic tools, they set us up with work clothes and work boots. They help give you a head start, they really support you.

What is one piece of advice you'd give someone who's wondering if a career in electrical is for them?

You've just got to go in and try it. You never know if you're going to like something if you don't try it. You have nothing to lose, you only have so much knowledge and experience to gain.

LIT UP LED

Building a circuit to light up an LED is a simple as sliding the diode's wires over a coin battery! Learning how electricity works in a safe, playful environment is a fun way to increase curiosity and confidence in working on electrical and electronic systems. Knowledge of simple battery-run DC systems can also help with visualization and troubleshooting car and boat wiring circuits and systems.

Teachers: this simple electrical investigation project also offers students an endless opportunity for applied design (a key curricular competency from both the ADST and science curricula in BC). Now that they have a tiny light, where can they imagine installing it? Could they use it to illuminate a toy or picture? Could it be used it as a flashlight or indicator light? For more advanced grades, you could have students designing switches to turn their light on and off, or they could incorporate the simple LED circuit into a device that solves a problem in their life. (Can it be used to light up the dark space in a cupboard? Could a series of several LEDs illuminate or indicate a path through a garden?)

Store your coin batteries in their original packaging so as not to accidentally create short circuits (which can result in battery damage or a fire hazard). Coin batteries are also harmful if swallowed; keep them away from pets and babies.

Materials

- Two or three lithium coin batteries (CR2032, CR2016 or similar)
- Two or three LEDs (3mm or 5mm, assorted colours)
- Electrical tape
- **Optional:** craft supplies such as construction paper, origami paper, paint, felt pens, cardboard, tape, etc.

Tools

- Just your hands!

Procedure

Prepare the power:

1. Play with the coin batteries and LEDs; can you make the LEDs light up? What parts of the LED and battery need to touch to make it work?

2. Look up labelled diagrams of an LED and of a coin battery. Use the following words to explain what you observed or learned: LED, wire, short, long, positive (+), negative (-), battery, terminal.

3. **Troubleshooting:** Does your LED not light up? Try a new battery. Try a new LED. Flip the battery around. Try bending the LED wires so they make better connection with the battery.

4. Make something fun with your lit-up LEDs! Use a wrap of electrical tape to hold your LED wires in place on the battery, then use it in one of the following projects.

Project Ideas

- Do you like origami? Fold a balloon or box and insert the lit-up LED into it before you finish folding it.
- Do you like collage and painting? Make a “stained-glass” lantern: paste scraps of colourful tissue paper onto an empty glass jar using white glue and a paintbrush. Place your lit-up LED inside and let it shine!
- Do you like vehicles? Choose and print a “printable paper car template” online, cut it out and tape it together, then add lit-up LEDs for headlights and taillights, etc.
- Do you like boats? Make a boat model and use lit-up LEDs for port (red) and starboard (green) navigation lights.
- Do you like sculpture? Use toilet paper tubes to make a house or dragon or robot or creature, decorate it, then cut or poke holes and insert your lit-up LED, hiding the battery inside the tube. The LEDs can become light-up eyes, or windows, or buttons - whatever you can imagine!
- Do you like play acting or dressing up? Make a cardboard crown, decorate it, then poke holes and insert lit-up LEDs to make light-up jewels!
- Can you think of other places you could be creative with your LED and battery?

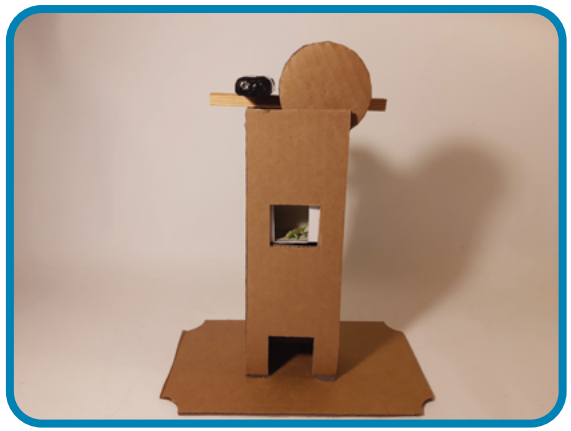
Extension Challenges

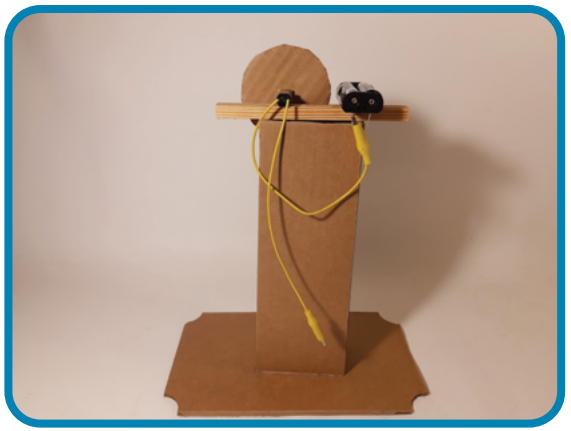
- Design a new light-up toy using what you know about LEDs and batteries.
- Make a switch mechanism that can turn your LED on and off so you don’t have to take the LED and battery apart each time.
- Design a device that uses a lit-up LED to solve a problem in your daily life (is that hall closet too dark to find anything in?), or develop an imaginary or real product you could market to people (do dogs need light-up collars for night walks?).

CIRCUIT CITY ELEVATOR

Electric motors are found all over cities moving everything from people to food to building supplies and more! Follow the procedure here to build a simple elevator using a DC “micro” gear motor for power; make one just for fun on its own, or create an entire “Circuit City” full of street lights, light-up buildings, vehicles, and more. Note: you can make a closed elevator shaft with cut-out doors at the different floors as shown, or you can make a simple 3-sided shaft with an open front to simplify the build.

Teachers: This project is a great way to cover the ADST curricular competencies of applied design (Ask students before they begin: Who will be using the elevator? What dimensions does it need to be? How tall will it need to be?). You can also get students learning math with their elevators (What height does the elevator go to? How much time does the elevator take to go from the bottom to the top? What rate does the elevator move at? What is the class average for these values?). The gear motor and AA battery holders are easily searched for and found online or at your local electronics/robotics store.





Materials

- N20 micro gear motor, 6V 30 RPM (or similar)
- One 2-cell AA battery holder, PC pin (breadboard compatible)
- Two AA batteries
- One connector wire with alligator clip ends
- Hot glue sticks or white glue
- ~3’ of string or ribbon
- Wood strip, e.g., paint stir stick, tongue depressor, or similar
- One big corrugated cardboard box, or similar stiff material
- Tape
- **Optional:** scrap thin cardboard (e.g., cereal boxes, found small empty boxes, etc.)
- **Optional:** lead-free solder wire for electronics

Tools

- Wire strippers
- Tape measure or ruler
- Pencil or pen
- Found round objects to trace ~ 2” and 3” diameter circles
- Scissors
- Needle, thumbtack, or similar
- Hot glue gun
- **Optional:** soldering iron
- **Optional:** Utility knife
  (for assisting adult use, if necessary)

Procedure

Prepare the power:

1. Use the wire strippers to cut your connector wire in half. (Consider swapping one of your halves with a classmate so you have two different coloured wires). Strip the last ½" of insulation from each wire.

2. Twist the wire ends to make a point then thread them about ¼" through the hole in one of the motor's terminals as shown. Fold the wire back onto itself and twist it like a twist tie to secure. Repeat with your second wire on the other motor terminal.

3. **Optional: If** you know how to use a soldering iron and solder, or you can ask a trusted adult to do this, adding a bit of solder on these connections to make them more durable.

4. Insert your AA batteries into the battery holder. Clip your two wires to the battery holder pins to test your motor. Note the direction the axle spins. Reverse the wires – which way does the axle spin?

Construct the hub:

5. Use some round objects to trace two large circles (about 3" in diameter) and two smaller circles (about 2" in diameter) onto a piece of corrugated cardboard.

6. Cut out the circles and poke a hole in the centre of each with a thumbtack. Widen the holes gently with a pencil point until they fit snugly over the gear motor axle.

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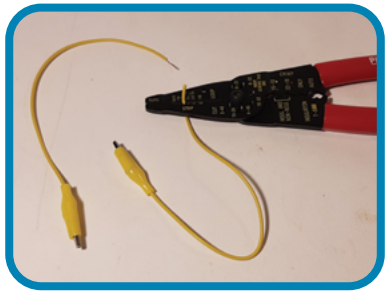

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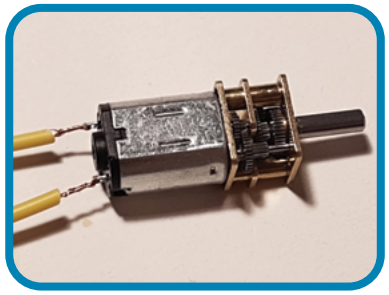

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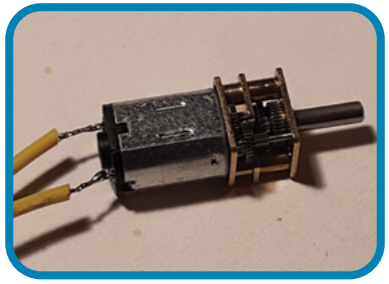

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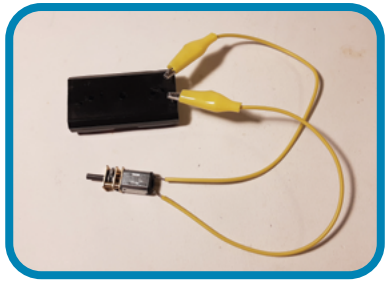

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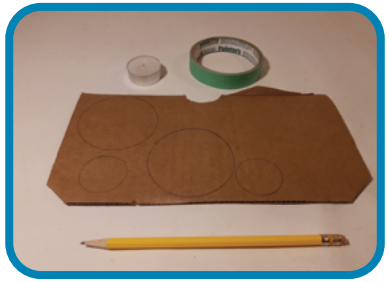


7. Use hot glue or white glue to stick the circles together in this order: big, small, small, big, with the centre holes lined up.

8. Use a tape measure to decide how tall your elevator needs to be; add 8" to this dimension and cut a piece of string or ribbon at that length. Add a dab of glue to the edge of the small cardboard circles, then lay your string into the hub like you're winding a spool of thread and tie it snugly in place.

Assemble the motor mechanism:

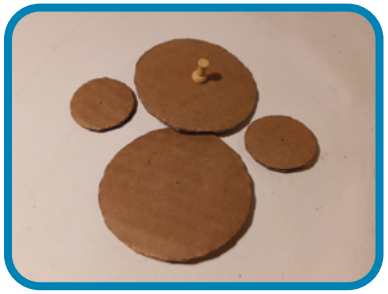
9. Glue the silver part of the gear motor body near the centre of the wood strip with the axle poking straight off to the side as shown. Make sure to keep the glue away from the motor's cogs.

10. Put a TINY dab of glue into the hole in the cardboard hub and carefully push the tip of the motor axle into the hole. Instead of pushing the hub on all the way, leave a small space between the motor body and the hub so the hub can rotate freely. Be conservative with your glue so it doesn't squeeze out into the motor's moving parts. Let the glue dry, keeping the motor axle 90° to the plane of the cardboard.

11. Glue the battery holder on next to the motor, keeping the prongs easily accessible to clip to.

Construct the elevator and shaft:

12. Find or make a small box that is the appropriate size or scale for your "Circuit City" people. Leave the bottom on and cut out a door hole.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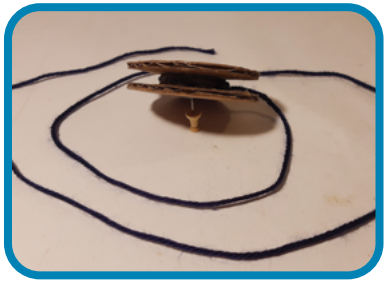
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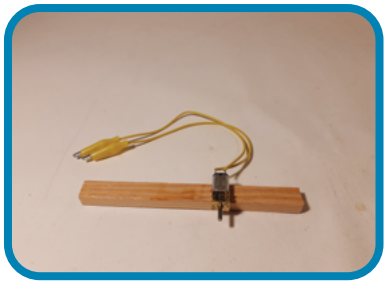
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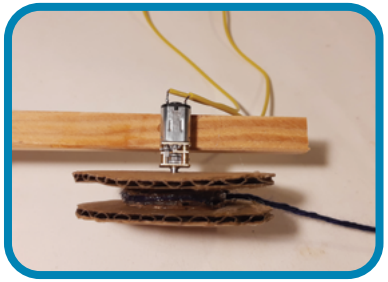
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13. Poke two holes in the top of your elevator box: one in the middle of the front (above the door), and one in the middle of the back. Push the string from your motor's hub through the two holes and tie it above the elevator as shown. Secure the string with a dab of glue at the holes if needed.

14. Measure the floor of your elevator box: length and width. Design an elevator shaft that is ½" larger in both dimensions than the elevator box so it will slide easily up and down inside. You will need to cut five pieces of cardboard: two strips for the sides, two for the front/back, and one bigger base piece to stand the elevator on.

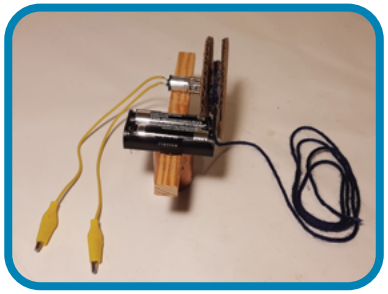
15. Cut out a bottom door in the front panel a bit bigger than your door hole in the elevator box.

16. Glue or tape the four shaft walls together.

17. Figure out where your "second floor" will be (as shown) and cut another door hole in the front of the elevator shaft. Ask an adult to help you with this step as it might be easiest to do this with a utility knife.

18. Lower the elevator box into the shaft and place the wood strip on the top. Position the hub so that the string falls down close to the middle of the shaft. You may need to cut away some cardboard from the top of the shaft if the hub doesn't fit. Glue your wood strip in place.

19. Attach the alligator clips to the battery holder prongs to make the elevator move. Reverse the clips to make the elevator move in the opposite direction. Be sure to stop the motor before the elevator reaches the very top so the motor doesn't burn out or cause damage to your creation.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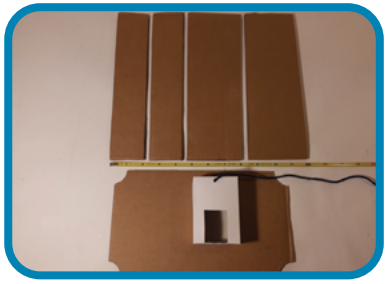
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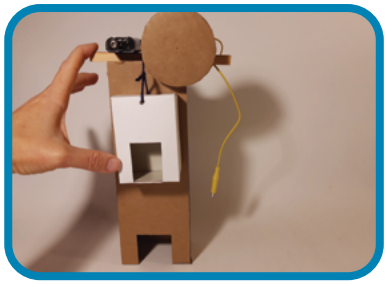
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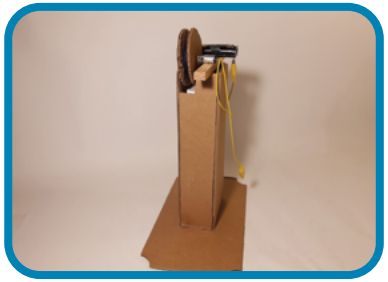
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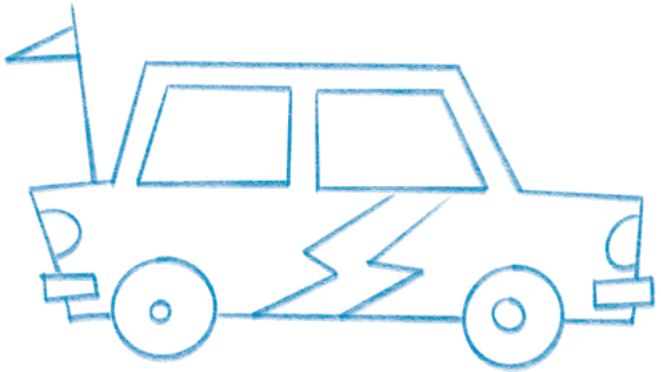
Troubleshooting

- Make sure not to get glue or string stuck in the moving cogs of your gear motor.
- Check your wire connections to make sure they are solid. Use fresh AA batteries.
- Check that there are no bits of extra glue or cardboard getting in the way of the moving parts.

Extension Challenges

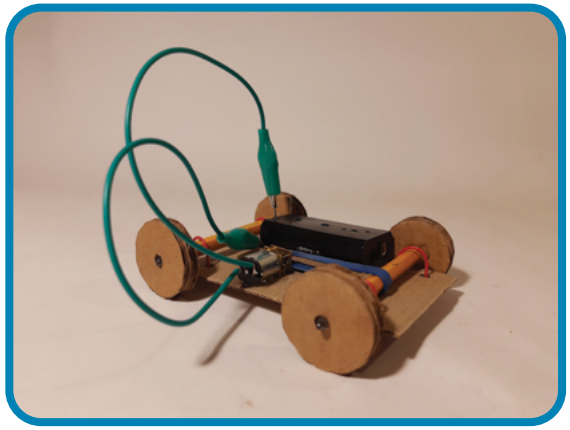
- Design and construct a building in which to install your elevator. Make more than one floor for the elevator to stop at.
- Can you use the elevator gear motor and hub to design other useful creations for your Circuit City? (e.g., crane, lifting bridge, escalator, conveyor belt, etc.)
- Install a “double pole double throw switch” into your circuit which will allow you to lift and lower the elevator without switching the alligator clips each time.

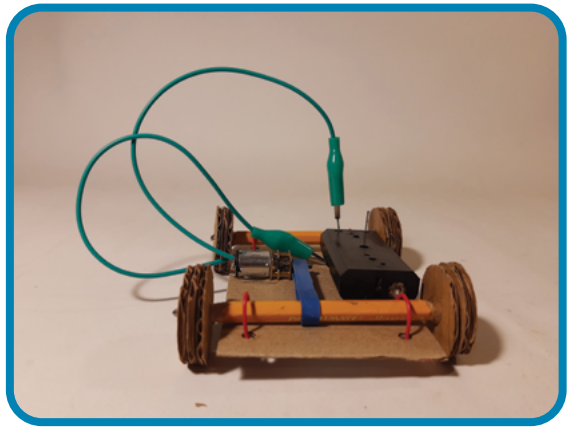


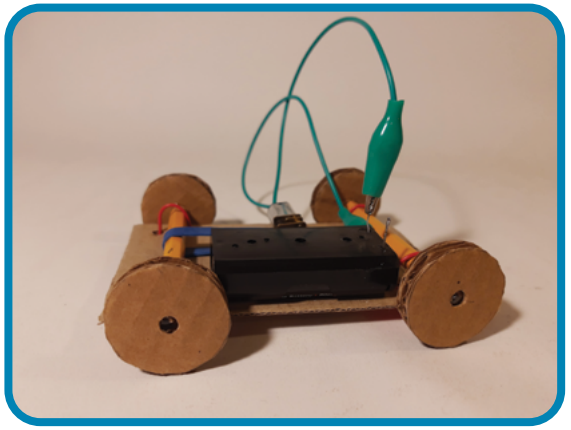
CIRCUIT CITY TRANSPORTATION

Learn some basics of circuitry and robotics while having fun making your very own toy vehicle! Follow the procedure to build the vehicle base and attach the motor, then hone your design and prototyping skills to make the exterior of your vehicle. This can be a stand-alone individual project, or you can create an entire "Circuit City" complete with different types of vehicles, lit-up buildings (see our "Lit-Up LED" project for more ideas), elevators, streetlights, etc.

Teachers: This is an ideal project to lead students through the Applied Design curricular competencies of the BC ADST curriculum: show them how to build the prototype as illustrated here, then have them redesign and make improvements to customize their own vehicle based on "user needs" in their Circuit City. This project can also be used to teach science (exploring and making devices that transform energy, designing scientific experiments to see what might make the vehicles drive faster), math (how can you measure the rate at which your vehicle drives? Can you convert these units to kmh? M/s?), social studies (what kinds of transportation are required to keep goods and people moving through a busy city?), etc. The gear motor and AA battery holders are easily searched for and found online or at your local electronics/robotics store.







Materials

- N20 micro gear motor, 6V 30 RPM (or similar)
- 8” ~12 to 18 gauge solid core wire (or similar)
- One 2-cell AA battery holder, PC pin (breadboard compatible)
- Two AA batteries
- One connector wire with alligator clip ends
- Two wood pencils or two pencil-sized dowels
- ~25 square inches of corrugated cardboard
- 3”x5” strong cardboard, plastic corrugated card, or thin, stiff plastic
- Hot glue sticks or white glue
- Wide, short elastic band (e.g., from a vegetable bunch)
- Tape
- **Optional:** lead-free solder wire for electronics

Tools

- Wire strippers
- Tape measure or ruler
- Found round object to trace ~ 1” diameter circles
- Pencil sharpener
- Hot glue gun
- Scissors or utility knife
- Hole punch (single)
- **Optional:** soldering iron

Procedure

Prepare the power:

1. Use the wire strippers to cut your connector wire in half. (Consider swapping one of your halves with a classmate so you have two different coloured wires). Strip the last ½" of insulation from each wire.

2. Twist the wire ends to make a point then thread them about ¼" through the hole in one of the motor's terminals as shown. Fold the wire back onto itself and twist it like a twist tie to secure. Repeat with your second wire on the other motor terminal.

3. Optional: If you know how to use a soldering iron and solder, or you can ask a trusted adult to do this, adding a bit of solder on these connections to make them more durable.

4. Insert your AA batteries into the battery holder. Clip your two wires to the battery holder pins to test your motor. Note the direction the axle spins. Reverse the wires – which way does the axle spin?

Prepare your pair of wheels and axles:

5. Trace twelve ~1" circles onto corrugated cardboard, then cut them out. Hole punch the centre of each circle.

6. Use the hot glue gun (or regular white glue) to stick three circles together to make one wheel. Repeat until you have four wheels made of three layers each.

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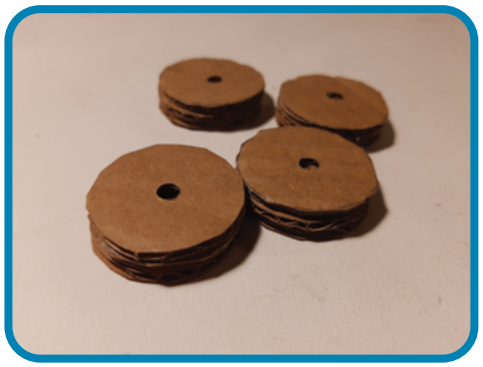

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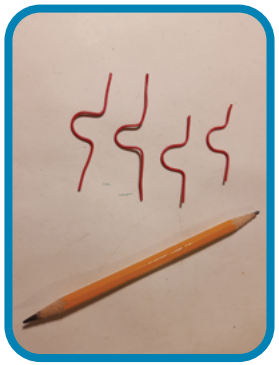

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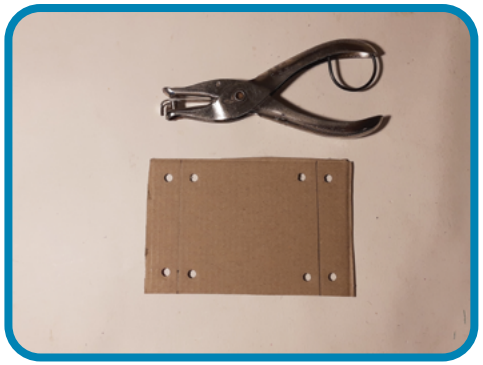


7. Sharpen both ends of the pencils or dowels until they measure 4” point to point. You may have to snap the eraser end off your pencils first – try using a pair of old scissors to crush the wood until you can snap the end off with your fingers.

Make the chassis (vehicle base):

8. Use the wire strippers to cut and bend four 2” pieces of wire into u-shaped brackets as shown. To keep the curves smooth, try bending the middle of each wire piece over a felt pen or dowel that is slightly bigger than your pencil diameter.

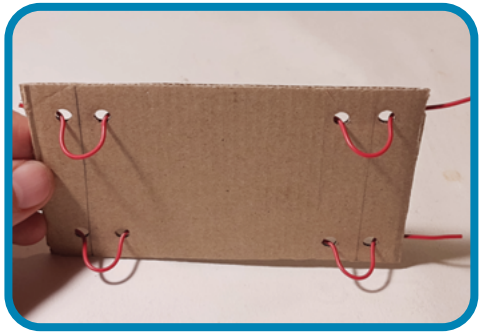
9. Use a ruler or speed square and pencil to mark two straight lines on your chassis to show where your axles will sit, approximately ¾” in from the ends. At each corner, use the hole punch to make two holes on either side of the lines (about ½” apart, and ½” in from the sides) as shown.

10. Insert the wires into the holes in the cardboard. Use your wire strippers or fingers to curve the ends of the wires so they sit flat on the cardboard and don’t poke over the edges. Glue them in place with hot glue and make sure they can’t wiggle around.

11. Insert your pencil axles and gently push the wheels onto the ends. Test your vehicle to make sure it rolls smoothly.

Put the vehicle together:

12. Remove one of your pencil axles, thread the elastic onto the middle section, then put it back together. Hook the other side of the elastic onto your gear motor axle and place your motor on the cardboard so the motor axle is parallel to the pencil. Pull your



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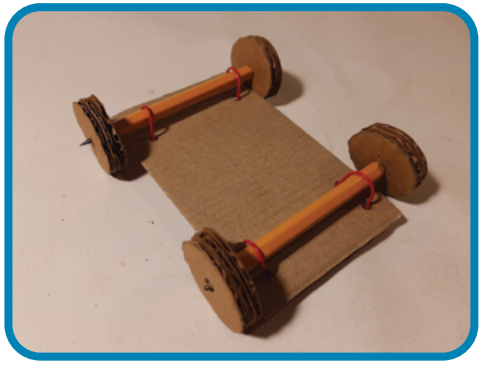

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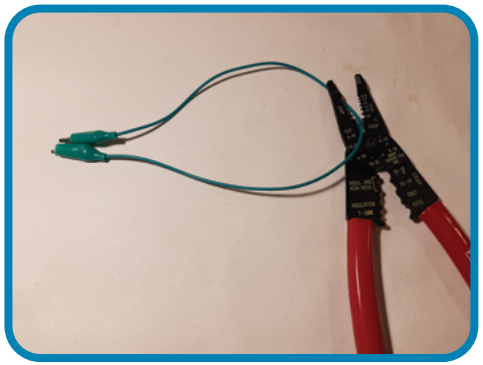

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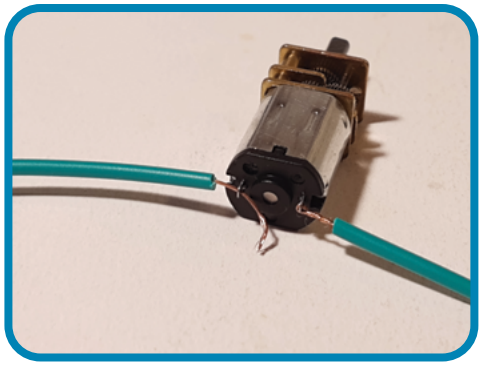

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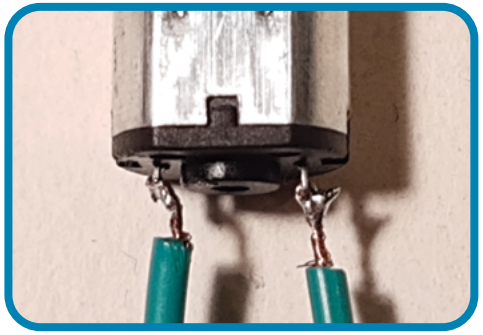
motor back gently until the elastic is taught, then ask a buddy to use a pencil to mark the motor's position on the cardboard while you hold it in place.

13. Unhook the elastic and carefully hot glue the motor to the cardboard. Make sure to glue only the silvery metal body of the motor and not get any glue into the space with the moving cogs.

14. Place the battery pack on the chassis and clip the alligator clips to the battery holder prongs to test your vehicle. See "Troubleshooting" for advice if your vehicle isn't driving. When you get it driving the way you want it to, hot glue your cardboard wheels onto the pencil ends, then tape or glue your battery holder to the chassis.

15. Design and make an exterior body for your vehicle: is it a transport truck? Is it a school bus? Is it a delivery van?



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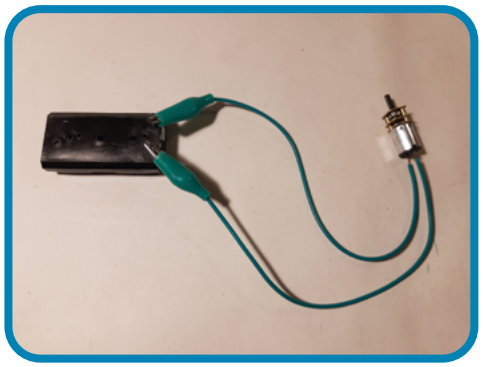

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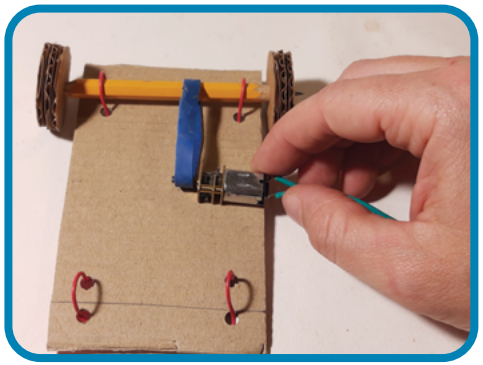

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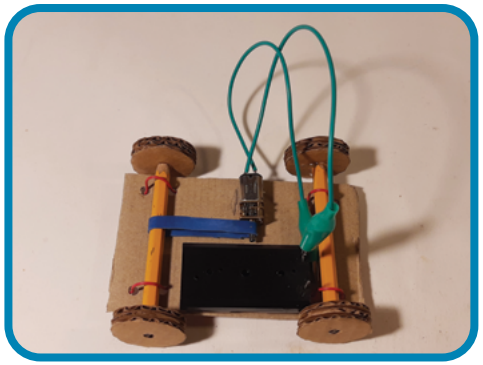

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Troubleshooting

- Is your vehicle not rolling? Inspect your chassis and wheels to make sure there's nothing to snag the wheels (eg, a blob of hot glue or a piece of cardboard). Adjust the wire loops as necessary so they don't pinch the axles.
- Are the axles not turning? Check that your elastic is taught enough to create the friction needed to hold it in place and stay attached to the motor axle. Consider angling your motor axle slightly AWAY from the pencil angle so that the elastic stays hooked on and doesn't "walk off" the end of the axle.
- Check your wire connections to make sure they are solid. Use fresh AA batteries.

Extension Challenges

- Make a design challenge: when you get your vehicle to the point that it can drive, mark out 1 foot on your desk top and time how long it takes your vehicle to drive that distance. Make some improvements to your vehicle to make it drive faster or more efficiently (is there rubbing and friction happening that you can prevent?). When you have finished your improvements, time your vehicle again. Record all the tweaks and improvements you make, and share the list with your peers. Can you all collaborate to get everyone's vehicles driving more quickly?
- Try experimenting with different sized hubs when connecting your axles to the motor. Many DC motors have a hard time turning when under a heavy load. If a small hub on the motor axle turns a big one on the vehicle's axle, it will be easier for your motor to turn. If a big hub on the motor axle turns a small wheel axle, the vehicle might drive very quickly, but it takes a lot of motor power to get it moving. How can you arrange the hubs to make your vehicle drive faster? Slower?
- Add 5mm LED bulbs to make headlights or taillights. You can make their own circuit with a 3V coin battery or one AAA battery, or you can add them to the circuit with the motor.
- Design a vehicle that drives in circles, or one that has a functioning steering wheel.
- Try wiring a "double pole double throw switch" into your circuit so you can make it go in forward and reverse without having to swap the alligator clips.

CURRICULAR CONNECTIONS

	Big Idea / Content	Bright Bracelet	Charge Card	Electromagnet	Electrical Fruit Salad	Energy Shake	Flashy Flounder	How to Use a Multimeter	Lit-up LED	Magic Matchbox	Make Your Own Connector Wires	Making Electricity	Pencil Resistors	Pick the Booger	Simple Motor	Wire Loop	Buzzer Game
Grade 3 ADST	Skills can be developed through play			●	●				●								
Grade 4 ADST	Designs can be improved with prototyping and testing		●	●	●			●									
Grade 5 ADST	The choice of technology and tools depends on the task				●			●			●			●		●	
Grade 6, 7, 8 ADST metalwork	Characteristics and uses of metals	●		●	●	●	●	●		●	●			●	●	●	
Grades 6, 7, 8 ADST textiles	Range of uses of textiles, hand construction techniques	●					●										
Grades 6, 7 ADST robotics	Main components of robots	●	●				●		●	●		●	●	●			
Grade 8 ADST robotics	Identification and applications of components	●	●		●	●	●		●			●	●	●			
Grade 6, 7 ADST power technology	forms of energy, devices that transform energy	●	●	●	●	●	●		●	●		●		●	●	●	
Grade 8 ADST power technology	conversion and transmission of energy, sources of energy		●	●	●	●		●	●		●	●	●		●	●	
Grade 1 science	"specific properties of materials allow us to use them in different ways"			●	●				●								
Grade 4 science	"devices that transform energy"		●	●	●				●								
Grade 5 science	"solutions & solubility"				●												
Grade 7 science	"electricity: generated in different ways with different environmental impacts"				●	●		●	●			●			●		
	"electromagnetism"			●		●		●		●	●	●			●		
Grade 8 science	"atomic theory and models", "electrons and leptons"	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Grade 9 science	"circuits must be complete for electrons to flow"	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	"voltage, current, and resistance"			●	●	●		●			●	●	●				

MATERIALS

		Bright Bracelet	Charge Card	Electromagnet	Electrical Fruit Salad	Energy Shake	Flashy Flounder	How to Use a Multimeter	Lit-up LED	Magic Matchbox	Make Your Own Connector Wires	Making Electricity	Pencil Resistors	Pick the Booger	Simple Motor	Wire Loop	Buzzer Game
Batteries + accessories	3V coin (CR2016 or similar)	1	1				1		2	1							
	9V			1				1					1		1	1	
	9V connector with alligator clip ends															1	
	AA batteries													3			
	3xAA battery holder with wire leads													1			
Metal components	large paper clip			1													
	nail (3")			1													
	galvanized roofing nail				5+												
	thumb tacks			2													
	small magnetic objects (eg, brads, pins)			20+													
	steel ball bearing (6mm diameter)									1							
	small binder clips										2						
	fork											1			2		
	aluminum foil													8"x11"			
	1" nuts													5			
	alligator clip ends															5O	
Electronic components	vibrating mini motor (2-5V DC)									1							
	hobby motor (1.5-6V) with lead wires attached												1				
	DC active buzzer															1	
Bulbs & LEDs	3mm LED	5 any colour	1 any colour		1 red	2 red	2	1	2			1 red, 1 yellow					
	5mm LED													1			
	tiny incandescent bulb (eg. 12V T3.25 miniature vehicle indicator light)												1				
Resistors	180 Ω													1			
Wire	stainless steel conductive thread	3'					3'										
	18 AWG enamelled copper wire														20"		
	24 AWG enamelled copper wire			18"													
	28 AWG enamelled copper wire					100' (feet)											
	12 gauge solid ground wire				12"+					8"						16"	
	14/2 wire															4"	
	thermostat or speaker wire										12"						
	fine electrical solder					O						O				O	
	connector wires with alligator clip ends				5+								3+	3	2	3	

MATERIALS

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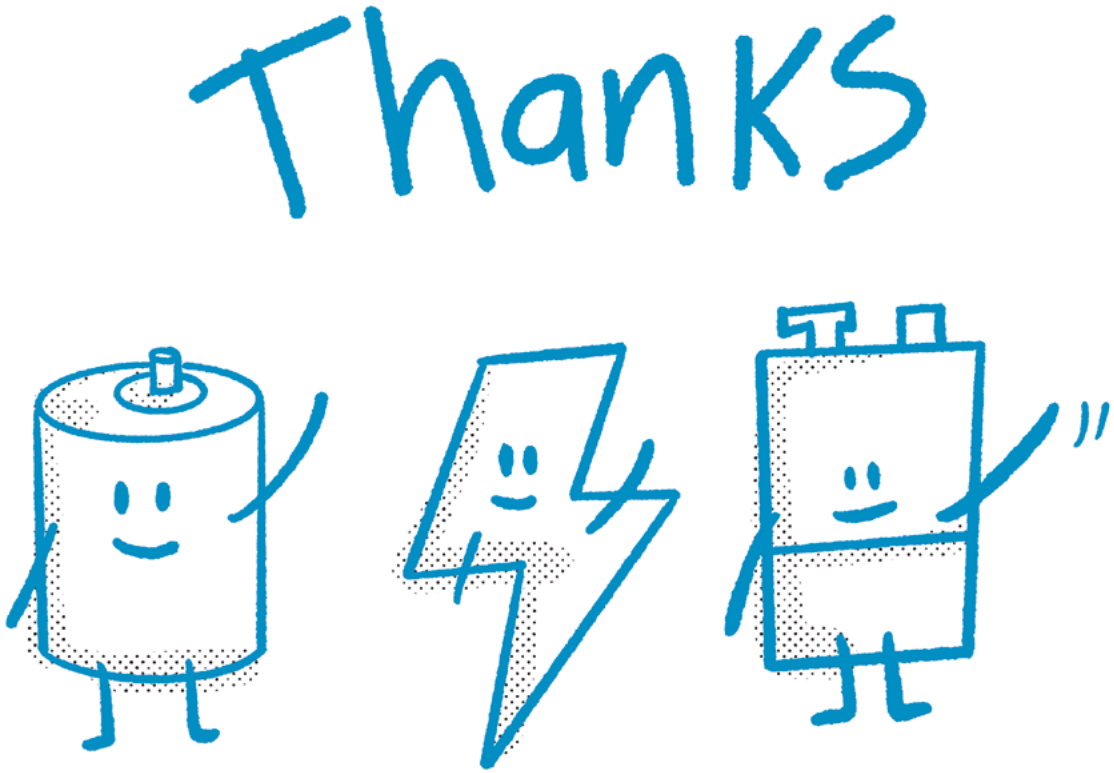
Sewing supplies	canvas or denim fabric scraps	2 1/2" x 8"															
	felt sheets (9"x12")						2 different colours										
	buttons (~1/2"-1" diameter)	2															
	regular thread	3'															
	embroidery thread	1'					3'										
	cotton balls						6										
	cloth ribbon (~1/2" wide)											3'					
	fishing line, any gauge											3'					
Paper	card stock or construction paper		1 sheet			1 sheet			●								
	scrap paper					1/8 sheet			●								
	sandpaper, any grit			1/8 sheet		1/8 sheet											
	white printer paper, 8.5"x11"													1 sheet			
	corrugated cardboard													~8.5"x11"			
Wood	softwood (eg common fir or similar)			1"x3"x4"												1"x4" x 8"	
Magnets	~20mm diameter, 5mm thick neodymium (~3/4" x 1/4")					3									2		
	~10mm diameter, 5mm thick neodymium (~3/8" x 1/4")									1							
Tape & glue	clear		●			●								●			
	electrical					●			●		●	●		●	●		
	copper or aluminum foil conductive tape									~1/4" x 6"							
	super glue														O		
Miscellaneous	matchbox (small)									1							
	cork											1					
	popcorn kernels													5+			
	plastic propellor (fits hobby motor axle)											O					
	mug or jar														1		
	juicy fruits and vegetables (eg, limes, kiwis, apples, etc)				5+												

*O (optional)

TOOLS

		Bright Bracelet	Charge Card	Electromagnet	Electrical Fruit Salad	Energy Shake	Flashy Flounder	How to Use a Multimeter	Lit-up LED	Magic Matchbox	Make Your Own Connector Wires	Making Electricity	Pencil Resistors	Pick the Booger	Simple Motor	Wire Loop	Buzzer Game
Measuring tools	tape measure	●		●		●										●	
	ruler		●														
	multimeter				●			●					O				
Writing utensils	black felt pen	●					●							●			
	pencil	●	●		●	●	●						5+	●			
	pencil crayons		●											●			
Hand tools	needle nose pliers	●					●			●			(to use as part of circuit)		●		
	linesman pliers															●	
	scissors	●	●				●			●	●	●		●	O		
	utility knife		●									●		●		O	
	small hand saw			●									O			●	
	wire strippers with cutter				●	●				●	●	●			●	●	
	pencil sharpener												●				
	cordless drill															●	
	1/8" drill bit															●	
Sewing	needle	●					●										
Electrical tools	hot glue gun	O					O										
	soldering iron					O						O					
Miscellaneous	found cylindrical object					~7/8" diameter, eg. candle/dowel				finger diameter					1" D	3/4" D	
	damp cloth				●												
	notebook				●												

*O (optional)



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