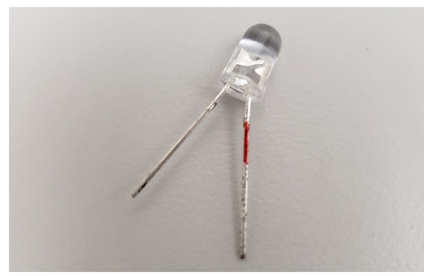
Be a Power Plant Engineer

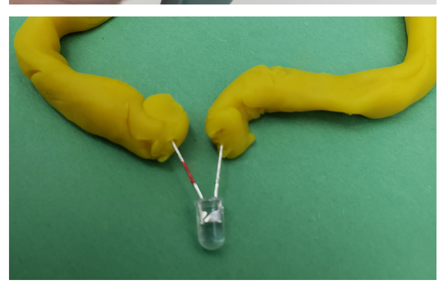
Physics Question: What factors affect how electrical energy flows through a circuit?

MATERIALS:

- Hand-crank power generators (1 per 3–4 students)
- Playdough (1 tub per 3–4 students)
- LED bulbs (3 per 3–4 students)
- Red permanent marker
- Pencils
- Lab notebooks
- Power Plant Engineer Career Card
- Optional materials:
  - Small plastic zipper bags or containers for bulbs
  - Tape or twist-ties

Prepare





1. Use the red marker to mark the long leg of each LED bulb.
2. Use the marker to draw an arrow pointing clockwise on the handle of each power generator.
3. If you reuse the materials with multiple groups of students, check the marks on the bulbs and the arrows on the generators periodically and refresh any that start to wear away.
4. (Optional) Put sets of three marked LED bulbs in small zipper bags or containers to help students keep track of them.
5. (Optional) The wires on the generators are often much longer than needed for this activity. Fold up some of the length of each wire and fasten with tape or a twist tie to keep it out of students' way.
6. Practice connecting the generator to an LED bulb until you are comfortable with the process:
   - Connect the red (+) wire of the generator to the red-marked long leg of the LED.
   - Connect the black (-) wire to the short leg of the LED.
   - Make sure the metal ends of the wires aren't touching each other. It may help to bend the legs of the LED outward to give more space.
   - Turn the crank of the generator clockwise to generate electrical current and light the bulb.
7. Practice setting up the circuit with playdough "wires" shown in the diagram on p. 17 of the lab notebook. This will help you identify potential challenges students may have and strategies for solving them.
8. Before beginning the activity, hang the "Research Lab" sign in a visible location. Have a generator and an LED bulb available for demonstration.

SAFETY NOTES

- **The electric current produced by the generators isn't strong enough to cause injury but could give someone a mild shock if they happened to touch both leads while it was active. To avoid this, ask students to *check that no one is touching the ends of the generator wires before starting to turn the crank*.**
- **Some hand-crank generators can generate enough electrical energy at top speeds to quickly burn out LED bulbs if connected directly. When demonstrating the generator with the LED, avoid cranking it at top speed, or for longer than a few seconds. *Encourage students to use playdough "wires" rather than connecting the generator wires directly to the bulb*. The playdough lowers the electrical energy so it is less likely to overpower the bulb.**

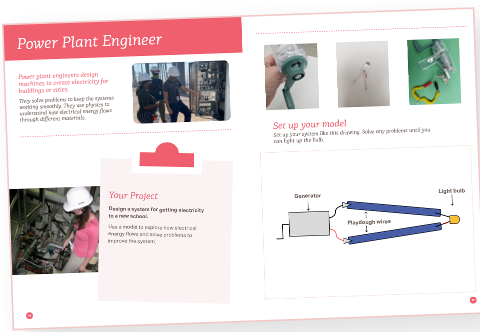
Engage

1. Introduce the power plant engineer career by showing the group the career card and asking questions to encourage students to think about what a power plant engineer might do:
   - *What do you notice about this picture? What do you think this person is doing?*
   - *Have you heard the word "engineer" before? What about "power plant?"*
   - *What do you think a power plant engineer might do?*
2. Explain that power plants create electrical energy that is used to power homes, schools, and other buildings. Power plant engineers figure out the best ways to create electricity for power plants and solve problems to make sure the electricity gets to the buildings that need it. **Make connections** to students' experiences with electricity:
   - *What are some things in your home that use electricity?*
   - *How do you think the electricity gets from the power plant to your home?*
   - *Have you ever been in a place where the power went out? What happened?*
3. Introduce the storyline of the activity like this:
   - Imagine we are a team of power plant engineers and this room is our research lab. What does our lab look like?
   - A new school is being built that needs its own power plant.
   - Our job is to figure out how to connect the power plant to the school building and solve any problems so the electricity flows smoothly.
4. Point out that to solve this problem, you'll need to think about **electrical energy**: where it comes from and how it can travel from one place to another. Introduce the hand-crank generator and **encourage scientific thinking** by inviting students to make observations and predictions about how it works. Test their ideas by demonstrating with the generator.
   - *What parts do you see in this generator? What do you think each one does?*
   - *What do you think I should do to make electricity with this generator?*
   - *Where do you think the electricity goes?*

5. Introduce the LED bulb. Ask the group to help you figure out how to get electricity from the generator to power the bulb. Test students' ideas by demonstrating with the generator until you have successfully connected both wires to the appropriate legs of the bulb and created a successful circuit.
    - *How could I get electricity from this generator to light up the bulb?*
    - *Did it work with just one wire attached? What else could I try?*
    - *What do you think will happen if I turn the crank slower or faster?*
6. Ask the group to draw conclusions about creating a successful electrical system:
    - *What did we figure out about getting electricity from a generator to something that needs power?*
    - *What's important to do or watch out for?*
    - *How could this help us when we're thinking about the power plant for the school?*

Explore

1. Point out that power plants, electrical wires, and buildings take a lot of work and money to build; you can't just tear them down and try again if they don't work the first time! When scientists need to study something that's too big or complicated, they use a **model**—a simpler or smaller version that can help them understand the real thing. You will use a model to work out problems and find the best way to connect the power plant to the school before you build it.
2. Introduce the parts of the model—hand-crank generator, LED bulb, and playdough. **Ask questions** to help students make connections between the parts of the model and the real-life system:
    - *What does the light bulb stand for in our real-life situation?*
    - *What could we do with playdough "wires" that we can't do with just the generator's wires?*
    - *How could that help us think about the power system for our school?*
3. Ask the group to look at the diagram on p. 17 of their lab notebook. Explain that your team has made a starting plan—a **prototype**—for testing how to connect the power plant and the school. Divide the group into research groups of 3–4 students and **cultivate rich dialogue** by asking pairs to look at the diagram and discuss how it connects to the parts of their model system.
    - *What parts do you see in the drawing?*
    - *What does it tell us about how to connect the parts of our model?*



4. Before distributing materials, discuss **safe practices for handling science tools**:
    - Make sure no one is touching the ends of the generator wires before turning the crank.
    - LED bulbs are small, sharp, and breakable; choose a safe place to keep them when you're not using them.
5. Give each group a generator, playdough, and 2–3 LED bulbs. Challenge them to set up their model based on the plan in their lab notebook and solve any problems they find until they can light up the bulb with the generator. Help students troubleshoot their systems by **asking questions** that compare their models to the diagram:
    - *What do you notice about how far apart the playdough parts are in the drawing?*
    - *The drawing shows a red mark on one leg of the bulb. Which wire is it matched up with?*
    - *What happens if you turn the crank in the other direction?*

FOR YOUNGER GROUPS:

- Read and discuss the diagram all together, as students may not be ready to read it independently.
- Setting up the model system according to the diagram and troubleshooting problems can be the focus of the activity, rather than changing or improving the design. Make a list of the problems the group found and solved to share with the team building the school's power plant.

6. Invite groups to make changes to their model, find out how each change affects the way electricity flows to the bulb, and think about what it might represent in the real-life system. Remind them to write or draw what they try in their lab notebooks.
   - *Does it matter if the playdough "wires" are longer or shorter? Thicker or thinner?*
   - *What happens if you crank faster or slower? What would that mean for the school's power plant?*
   - *What if the school wanted to add a second building? Can you change your model to light up two light bulbs at once?*
   - *What else could you change about the model? How do you think it will change the electricity going to the light bulb?*

Reflect

1. Gather the whole group together. **Cultivate rich dialogue** by discussing the results of the team's research:
   - *What did you find out about getting electricity to flow from the generator to the light bulb?*
   - *What problems did you find? How did you solve them?*
   - *What changes did you make to the model? What effect did they have?*
   - *What should we tell our team about the best ways to design the power plant to get electricity to the school?*
2. Encourage the group to reflect on how they were like power plant engineers during the activity. You may want to show the power plant engineer career card again, or refer to the science skills stickers in their notebooks:
   - *What are some of the things we did today as power plant engineers?*
   - *How did we think like scientists? What science skills did we use?*
   - *What did you do today that made you feel like a scientist?*
3. Allow time for students to draw or write their reflections in their lab notebooks. Invite them to choose a science skills sticker that reflects a skill they used and add it to their notebooks.

Extend

- Invite students to add insulating materials, such as craft foam sheets or bubble wrap, to their models. How can these materials change the placement of the playdough "wires" in the system?
- Make a batch of insulating, or non-conductive, playdough. (Recipes are widely available on the internet.) Encourage students to explore how electricity travels differently between the two types of playdough. Challenge them to use the two types of dough along with the generator and LED bulbs to build a 3D model of the school and its power plant; or invite them to design their own light-up creations. Which dough will they use for which parts of the design?
- Research methods of power generation, such as wind, solar, hydroelectric, or coal. Ask students to choose which method they would use for the school's power plant and draw or build a model of what their power plant could look like.

Background

- **Electricity is a kind of energy created by the movement of tiny particles** called electrons. When electrons flow freely from one place to another, they create electrical current. This electrical energy can be used to power many different machines and devices, from computers to toasters to vehicles. Most machines convert electrical energy into a different form of energy; for example: lamps and computer screens turn electrical energy into light energy, fans and electric bikes turn electricity into motion energy, and toasters and space heaters turn it into heat energy.
- **For electricity to flow freely, it needs to move in a continuous loop, or circuit**, starting from a power source and returning to the same source. To light a light bulb, for example, electricity must flow from the power source through the bulb and back to the power source. If the flow is interrupted, or if there is another path back to the source that bypasses the bulb, electricity won't flow through the bulb, and it won't be lit.
- **Some materials (conductors) allow electric current to flow through them, while others (insulators) stop electric current from flowing**. Electrical circuits use conducting and insulating materials to control how and where the electricity flows. Many metals, for example, conduct electricity, but rubber and most plastics do not. Most electrical wires are made of copper or steel with a coating of rubber or plastic. Electric current flows along the metal wire, but the insulating coating stops it from flowing into anything that might touch the wire (like your hand!)
- **Power plants** generate large amounts of electricity to supply power to communities. They convert other forms of energy, such as heat energy from burning coal or motion energy from water falling over a dam, into electric current. **Power plant engineers** design machines and systems to generate electrical current and deliver it where it is needed. They might improve systems to convert energy more efficiently or monitor the parts of the power plant and solve problems when they don't work as planned.
- **The hand-crank generators used in this activity convert motion energy into electricity**. Turning the crank rotates a magnet inside a coil of wire, causing the electrons in the wire to move and creating electrical energy. If the generator's two wires are connected by something that conducts electricity (such as a light bulb), the circuit is completed and electric current flows through the system. Reversing the direction of the crank changes the direction that the current flows; one direction sends the current out the red wire while the other direction sends the current out the black wire. Current direction is important in this activity, because the **LED bulbs only respond to electrical current in one direction**.

Power Plant Engineer Quick Guide

ACTIVITY SECTION	DO	ASK
Engage	Use career card to discuss career **Introduce story:** • A new school building needs its own power plant • Find the best way to set up the plant so electricity flows smoothly Demonstrate generator and LED bulb Discuss conclusions about how electricity flows	*What do you think this person is doing?* *Have you heard the words "power plant" or "engineer" before?* *How do you think electricity gets from the power plant to your home?* *How could I get electricity from this generator to light up the bulb?* *What did we figure out about getting electricity from a generator to something that needs power?*
Explore	Introduce model system Build & troubleshoot system based on prototype diagram Make changes to system & observe results	*What does the light bulb stand for in our real-life situation?* *What do you notice about how far apart the playdough parts are in the drawing?* *What else could you change about the model? How do you think it will change the electricity going to the light bulb?*
Reflect	Discuss results Report conclusions Reflect on career connections Use stickers & notebook to draw/write reflections	*What problems did you find? How did you solve them?* *What should we tell our team about the best ways to design the power plant to get electricity to the school?* *How were we like power plant engineers today?* *What science skills did you use?*