

# ACTIVITY 2

# Traveling Charges

*(Insulators and conductors)*

## Table of contents

**Page 2: Human Circuit:** Use a static charge to test whether people conduct electricity (level 1).

**Page 4: SOS:** Investigate switches and use them to send messages in Morse Code (level 2).

**Page 7: Types of Circuits:** Explore how the type of wiring affects the brightness of a set of light bulbs (level 2).

**Page 11: Electromagnets:** Make a simple electromagnet and test its strength (level 2).

**Page 15: Homemade Light Bulb:** Demonstrate how a light bulb filament works using thin wire (level 2 demonstration).

## Safety

Please note that while following the precautions in this guide can help teachers foster inquiry in a safe way, no guide could ever predict all of the problems that might occur. Good supervision and common sense are always needed.

## FOR THE TEACHER

# Human Circuit

(Level 2)

This activity is a quick and memorable way to show that people are conductors. Each individual in a connected circle of people will feel a shock as it is discharged around the loop.

We recommend using a Leyden Jar (like the one made on Page 6 in the *Opposites Attract* section) as the static electricity source, but other sources work as well. One alternative is the *Light and Sound Ball*\*\* that lights up when a circuit is completed.

\*\*Available from the ABoyd Company: <http://www.aboyd.com/prodinfo.asp?number=SAF%206521-18>

## Safety

Everyone that participates in this activity will get a small shock. Although the shock is not dangerous, students should be told what to expect and given the option not to participate.

This experiment should only be done with small amounts of static electricity, so use only the Leyden Jar from Page 6 in the *Opposites Attract* section or another safe source such as the *Light and Sound Ball*.

## Materials

- Static electricity source (charged Leyden Jar)
- People

## Instructions

1. Charge the Leyden jar (or other static source, if necessary).
2. Have students stand in a circle holding hands.
3. Enter the human circuit holding the Leyden jar by the aluminum foil only in your right hand, and join hands with the student on your left.
4. On your signal, the student on your right side should touch the nail, completing the circuit. If all students are all holding hands as instructed, everyone will feel the shock as it travels around the circle.
5. Repeat the experiment at least once more to show that the results are consistent.

## Discussion questions

- Are people conductors? How do you know from our experiment? Did the results agree with your prediction?
- Why is it important that everyone hold hands? What would happen if one person was wearing mittens?
- What are other safe ways you can test whether people are conductors or insulators?
- What part of your body did you feel the shock in as it traveled around the circle?

### Discussion

Salt water is a decent conductor of electricity, and since the human body is about 70% water and contains lots of salt, the human body is also a conductor. People usually feel the shock most strongly in their wrists because the electricity travels from one hand to the other primarily through the blood.

### Suggested resources

Zavisa, John. "How Lightning Works." How Stuff Works.

<http://science.howstuffworks.com/lightning.htm>

*Information on lightning and safety. Use the table of contents at the bottom of the page to find more information.*

### Bibliography

Goldberg, Jeanne. "Shocking Evidence!" WVIZ, Educational Services.

[http://www.wviz.org/edsvcs/projects/NTTI/Lesson\\_Plans/01\\_Shocking\\_Evidence.asp](http://www.wviz.org/edsvcs/projects/NTTI/Lesson_Plans/01_Shocking_Evidence.asp)

# SOS

Wire a switch into a circuit – the kind of switch used in telegraphs.

## Safety

You will be working with wires and batteries in this activity. Use the materials only as described in the directions because the wires are sharp and electricity can be dangerous.

## Materials

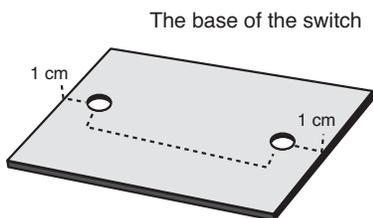
- Miniature, incandescent light bulb, around 4v
- Miniature light bulb holder
- 3 wires with alligator clip ends
- 2 metal paper fasteners
- Nail
- 2 D batteries
- 3 paperclips
- Piece of cardboard, 7-cm x 3-cm
- Tape

## Instructions



1. Tape the two batteries together, positive end to negative end.

2. Tape a paperclip to each end of the battery system, as in the core activity.

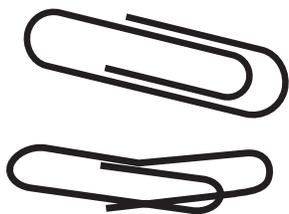


3. Cut a piece of cardboard 7-cm x 3-cm.

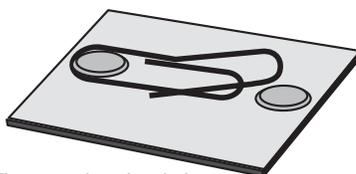
4. Use the nail to poke a hole in the cardboard, 1-cm from the edge of the cardboard

5. Poke a second hole a paperclip length away from the first hole.

6. Trim the cardboard so that the second hole is 1-cm from the end.

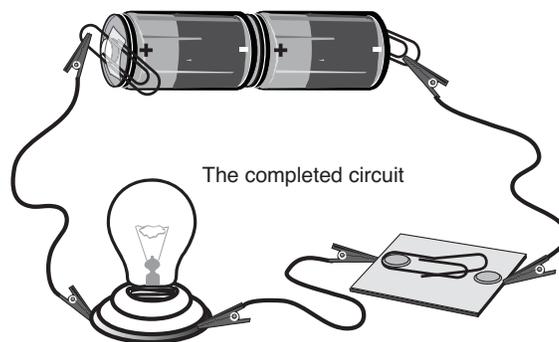


7. Bend a paperclip near the middle so that the longer loop sticks up slightly.



8. Place the fastener through the paperclip and then through the cardboard as shown in the picture, and secure it at the back by unfolding the legs of the fastener.

9. Push the other paper fastener through the second hole (do not put it through the paperclip) and secure it by unfolding the legs. Make sure that the legs of the two fasteners do not touch on the underside of the cardboard.



10. Place the switch on top of an insulating surface (such as cardboard).

11. Connect the switch and bulb base to the batteries as shown.

12. Press down on the paperclip to make it connect with the free fastener. The light bulb should light up.

## **Troubleshooting**

**Some things to check if the bulb does not light up:**

- Is there good contact at ALL connection points? (check between the batteries too)
- Are the batteries charged?
- Has the bulb burned out, or is it not screwed all the way into the base?

## **Discussion questions**

- How does your switch take advantage of the different properties of insulators and conductors?
- What types of things run on switches? What are the main advantages of wiring something to a switch?
- If you wanted to send an auditory Morse code message instead of a visual one, what would change about your set-up?

# FOR THE TEACHER

## SOS

(Level 2)

### Materials

- Miniature, incandescent light bulb, around 4v\*  
*These are available from science supply stores, such as Science Kit & Boreal Labs, <http://sciencekit.com>, part number WW6221004. \$15.50/pack of 10.*
- Miniature light bulb holder\*  
*These are available from science supply stores, such as Science Kit & Boreal Labs, <http://sciencekit.com>, part number WW6004100. \$15.95/pack of 12.*
- 3 wires with alligator clip ends  
*Called "Insulated Test / Jumper Leads", you can usually find a pack of 10 for less than \$6. If not available at a local hardware store or RadioShack, you can purchase them from RadioShack.com, model 278-1156.*
- 2 metal paper fasteners  
*Available in the office section of retail stores such as Target and Wal-Mart, as well as office supply stores.*
- 2 D batteries
- 3 paperclips
- Piece of cardboard, 7-cm x 3-cm
- Tape
- Scissors
- Nail

### Notes on the activity

If you have time, you may want to hand out a Morse Code table (easily findable on the internet) and let students send messages to each other.

After completing this activity, you may want to challenge students to create different kinds of switches – such as switches that are on by default or that allow electricity to flow in different configurations. Additional materials will be needed for this.

### Discussion

In this activity, students have created a simple switch that is off by default – the bulb only lights up when you press down on the paperclip so that it is touching both fasteners and completing the circuit.

### Suggested resources

Bellis, Mary. "The History of the Telegraph and Telegraphy." About.com  
<http://inventors.about.com/library/inventors/bltelegraph.htm>  
*Tells the history of the telegraph and Morse code.*

### Bibliography

Glover, David. Batteries, Bulbs, and Wires: Science Facts and Experiments.  
New York: Kingfisher, 1993. Pages 17, 20

# Types of Circuits

(Level 2)

Explore how wiring affects the brightness of the bulbs.

## Safety

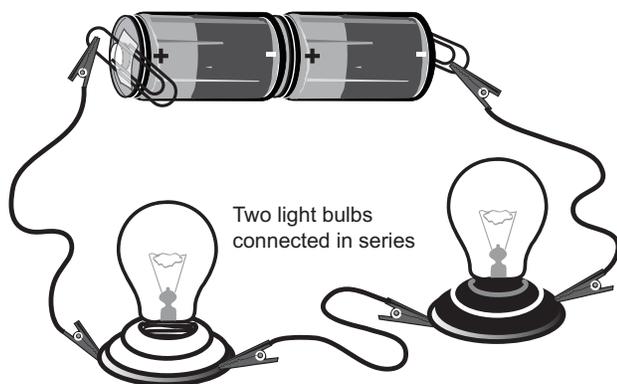
You will be working with wires and batteries in this activity. Use the materials only as described in the directions because the wires are sharp and electricity can be dangerous.

## Materials

- 2 miniature light bulbs
- 2 miniature light bulb holders
- 4 wires with alligator clip ends
- 2 D batteries
- 2 paperclips
- Adhesive tape

## Instructions

1. Tape the two batteries together, positive end to negative end.
2. Tape a paperclip to each end of the battery system, as in the core activity.
3. Create a single bulb circuit, by connecting the base of the bulb to the paperclips. Make sure the light bulb lights up.
4. Disconnect the wire from one end of the battery system, and clip it instead to the second light bulb.



5. Use another wire to clip the free screw on the base of the second light bulb to the free end of the battery system

6. Observe the brightness of the bulbs. Are they brighter, dimmer, or the same brightness as when there was only one bulb in the circuit?

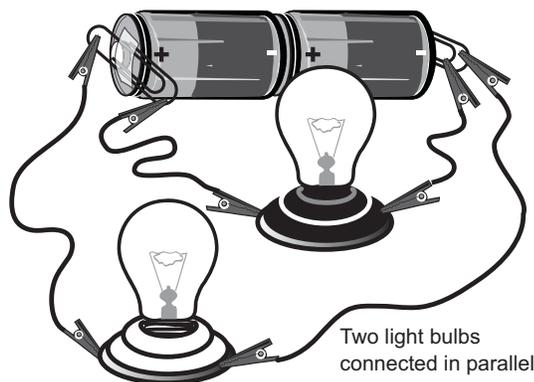
7. Unscrew one light bulb and record what happens.

8. Disconnect the second light bulb.

9. Connect the second bulb to the batteries again, this time in the same way that the first one is connected. You will need two additional wires for this.

10. Observe the brightness of the bulbs. Are they brighter, dimmer, or the same brightness as when there was only one bulb in the circuit?

11. Unscrew one bulb and record what happens.



## **Discussion questions**

- If you wanted to create a row of bright light bulbs, how would you wire them?
- Which kind of wiring would cause the batteries to run out sooner? Why?
- What happened in each case when you unscrewed one of the bulbs? Why?
- What kind of wiring do you think the circuits in your classroom use? How could you find out?

# FOR THE TEACHER

## Types of Circuits

(Level 2)

Explore how wiring affects the brightness of the bulbs.

### Materials

- 2 miniature, incandescent light bulbs, around 4v

*These are available from science supply stores, such as Science Kit & Boreal Labs, <http://sciencekit.com>, part number WW6221004. \$15.50/pack of 10.*

- 2 miniature light bulb holders

*These are available from science supply stores, such as Science Kit & Boreal Labs, <http://sciencekit.com>, part number WW6004100. \$15.95/pack of 12.*

- 4 wires with alligator clip ends

*Called "Insulated Test / Jumper Leads", you can usually find a pack of 10 for less than \$6. If not available at a local hardware store or RadioShack, you can purchase them from RadioShack.com, model 278-1156.*

- 2 D batteries
- 2 paperclips
- Adhesive tape

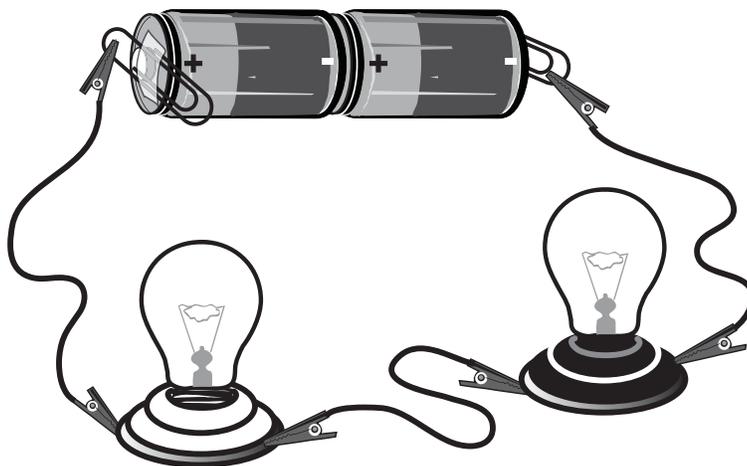
### Discussion

The brightness of two otherwise identical light bulbs in a circuit is determined by the amount of current flowing through them. The amount of current flowing through a circuit depends on the resistance and voltage of the circuit. A light bulb is a source of resistance in a circuit.

- **Current:** The number of electrons that pass a certain point per second; a high current means that many electrons pass a given point each second.
- **Resistance:** How easy it is for the electrons to travel; a higher resistance means that it is harder for electrons to travel though the circuit.
- **Voltage:** The force motivating electrons to flow; a high voltage means electrons are very motivated to move.

When a light bulb is added to a series circuit:

- **Current:** The current decreases. Think of current as a flow rate (electrons passing per second) – if you imagine the electrons being slowed down by the first light bulb and then being slowed down again by the second light bulb, you can see how it would create a "traffic jam" effect and slow down the flow.
- **Resistance:** The electrons have to travel through two light bulbs, so the resistance increases from a one light bulb circuit.
- **Voltage:** The total voltage of the circuit is constant since the battery system is always at 3volts.

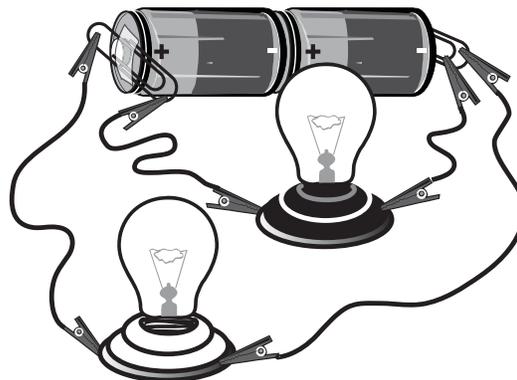


This means that less current flows through a series circuit with two bulbs than a single bulb circuit, so the light bulbs are dimmer.

When you unscrew one of the light bulbs in a series circuit, you break the circuit and the other light bulb goes out.

When a light bulb is added to a parallel circuit:

- **Current:** As you add more branches to a circuit, you increase the overall flow rate – thereby increasing the current. This is like a new lane being opened up to ease traffic.
- **Resistance:** Since you have these alternate branches, or “routes”, it is easier for “traffic” to flow through the circuit, meaning that resistance has gone down.
- **Voltage:** The total voltage of the circuit is constant since the battery system is always at 3volts.



This means that overall more current flows through a parallel circuit of two bulbs than a single bulb circuit. However, the current is split between the two different paths, so each bulb gets about the same amount of current it would have if it were the only bulb in the circuit.

When you unscrew one of the light bulbs, you break the circuit, but only along one branch. This means that you now have a one bulb circuit, with some extra wires hanging off of it.

## Suggested resources

“Electric Circuits” School Science.

<http://www.schoolscience.co.uk/content/3/physics/circuits/circh2pg1.html>

*Contains more information on series and parallel circuits (click “next” for information on parallel circuits). Also check out the “circuit challenges.”*

## Bibliography

“Light Bulb Circuits.” Family Science Physics

[www.science.tamu.edu/CMSE/fmsn/LightBulbs.doc](http://www.science.tamu.edu/CMSE/fmsn/LightBulbs.doc)

Pelak, Kelly. “Electricity Unit: Circuits”, 1997

[http://www.ed.uiuc.edu/YLP/96-97/96-97\\_curriculum\\_units/Electricity\\_KPelak/circuits.html](http://www.ed.uiuc.edu/YLP/96-97/96-97_curriculum_units/Electricity_KPelak/circuits.html)

# Electromagnets

(Level 2)

Create a temporary magnet using electricity – and then investigate how to change the strength of the magnet.

## Safety

This activity requires you to work with wire and nails (or other sharp objects) that could be dangerous. Be careful when holding the electromagnets and only turn on the electromagnet for short periods of time. Disconnect the electromagnet if you feel it getting warm.

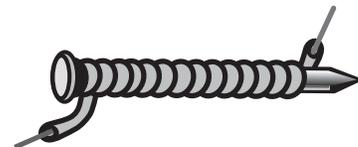
## Materials

- 6-cm long bolt
- 1-m of 20 gauge insulated copper wire
- Wire strippers or strong scissors
- 2 wires with alligator clip ends\*
- 2 D batteries
- Paper clips (several)
- Adhesive tape

## Instructions

1. Tape the two batteries together, positive end to negative end.
2. Tape a paperclip to each end of the battery system, as in the core activity.
3. Strip away 1-cm of insulation from each end of the wire.

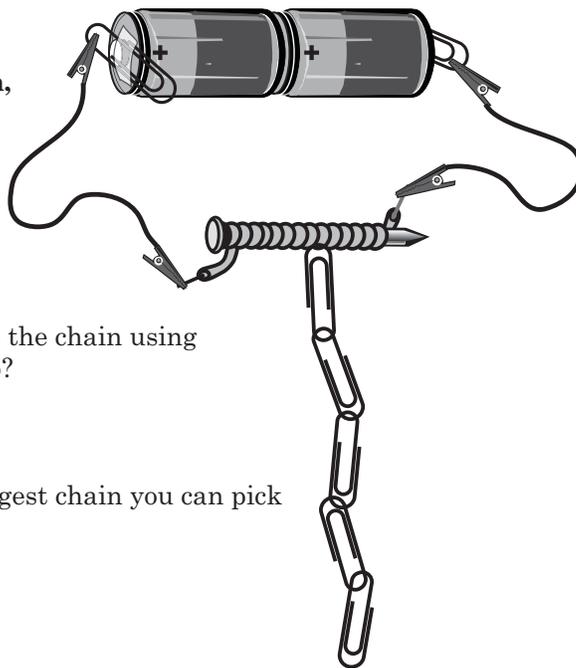
4. Neatly and tightly wrap the wire around the nail 30 times, leaving at least 3-cm of wire sticking out at both ends. Wrap the wire in only one direction, as shown in the picture.



5. Connect an alligator clip wire from the end of the wire coming off of the nail to the battery system.
6. Connect the other alligator clip wire from the nail to the free end of the battery system - this creates a complete circuit.

**WARNING: If you feel the electromagnet getting warm, turn it off immediately. Only keep the electromagnet on for short periods of time, otherwise you will drain the battery quickly.**

7. Bring the nail near the pile of paper clips and observe what happens.
8. Link some of the paperclips into a chain and try to pick up the chain using the electromagnet. What is the longest chain you can pick up?
9. Disconnect the battery system and take off 5 loops.
10. Reconnect the nail to the battery system. What is the longest chain you can pick up now? Record this information.
11. Repeat Steps 9-10 a few times.
12. Graph your data.



## **Discussion questions**

- How does decreasing the number of wire loops around the nail affect the strength of the magnet?
- Is there a limit to how strong you can make your electromagnet? If so, how many loops does it take to reach this limit?
- Can you still pick up paperclips after disconnecting the battery system? Why or why not?
- Besides changing the number of loops, how else could you change the strength of the magnet?

## FOR THE TEACHER

# Electromagnets

(Level 2)

Create a temporary magnet using electricity – and then investigate how to change the strength of the magnet.

## Materials

- 6-cm long bolt
- 1-m of 20 gauge insulated copper wire  
*This wire is also called “Bell Wire” and can be found in the doorbell section of hardware stores. It costs about \$5.00 for 65’ (20-m).*
- Wire strippers or strong scissors
- 2 wires with alligator clip ends\*  
*Called “Insulated Test / Jumper Leads”, you can usually find a pack of 10 for less than \$6. If not available at a local hardware store or RadioShack, you can purchase them from RadioShack.com, model 278-1156.*
- 2 D batteries      ■ Adhesive tape      ■ Paper clips (several)

## Discussion

When current flows through a tightly coiled wire it creates a strong magnetic field in the space inside the loops. The strength of this magnetic field is proportional to the number of loops – for example an electromagnet with twice as many loops has a magnetic field twice as strong.

If you coil this wire around an iron core, such as a nail, the magnetic field is intensified. This is because the nail becomes a temporary magnet under the influence of the magnetic field from the coiled wire. When the current is disconnected, the magnetic field created by the coiled wire disappears and the nail quickly loses its magnetization.

The strength of the magnet also depends on the amount of current passing through the wire (you can investigate this by changing the number of batteries). The strength of the magnetic field is also proportional to the current – an electromagnet with twice as much current has a magnetic field twice as strong.

Electromagnets are useful because you can control the strength of the magnet by controlling the current. This means that you can easily turn them on and off.

Electromagnets are used in junkyard cranes to lift and then drop cars, in particle accelerators where magnetic fields are used to direct beams of particles, and in magnetic levitation trains such as those in Germany and China.

## Suggested resources

Kurtus, Ron. “Electromagnetism.” School for Champions, 2005.  
<http://www.school-for-champions.com/science/electromagnetism.htm>  
*A detailed explanation of electromagnetism.*  
 “Maglev Train.” Wikipedia. [http://en.wikipedia.org/wiki/Maglev\\_train](http://en.wikipedia.org/wiki/Maglev_train)

*Go here to find out more about levitating trains and where they are used.*

### **Bibliography**

Glover, David. Batteries, Bulbs, and Wires: Science Facts and Experiments.  
New York: Kingfisher, 1993. Page 25

Kurtus, Ron. "Electromagnetism." School for Champions, 2005.  
<http://www.school-for-champions.com/science/electromagnetism.htm>

## FOR THE TEACHER

# Homemade Light Bulb (Level 2 demonstration)

This activity uses household items to create a simple light bulb. **This extension is best done as a demonstration, as safety is a significant concern.**

Please test this demonstration before performing it for your class, as results can vary depending on the type of wire used, battery strength, and filament length. Also be aware that the batteries will drain quickly from repeated demonstrations of this effect.

## Safety

- The filament in this demonstration gets VERY HOT. Do not touch it for at least a full minute after power has been disconnected. The connecting wires may also become hot. Be very careful when handling the wire at all times.
- The filament may smoke – avoid inhaling this smoke.
- Wash your hands after handling picture hanging wire.

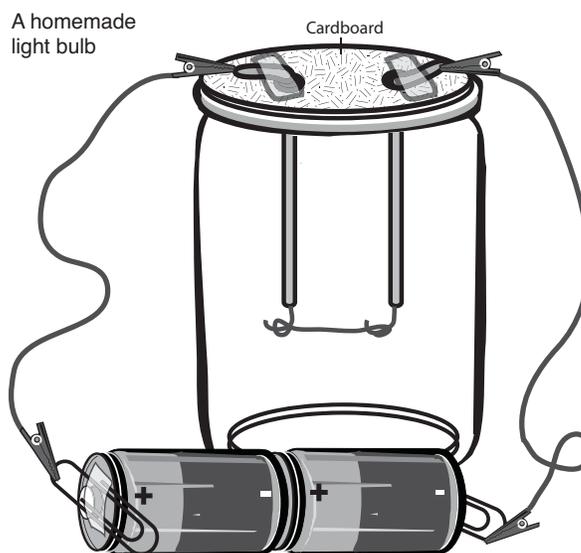
## Materials

- Large glass jar  
*Available in the baking aisle of many grocery stores and the house wares section of retail stores such as Target and Wal-Mart.*
- Picture hanging wire and/or 32 gauge nichrome wire  
*Picture hanging wire is available at hardware stores. Although harder to find, nichrome wire makes a great demonstration because it glows significantly longer than picture hanging wire before burning out. You can purchase nichrome wire at PnJ Resources, LLC, [http://www.pnjresources.com/Nichrome\\_page.htm](http://www.pnjresources.com/Nichrome_page.htm), for about \$2/10' spool.*
- 2 Wires with alligator clip ends\*  
*Called "Insulated Test / Jumper Leads", you can usually find a pack of 10 for less than \$6. If not available at a local hardware store or RadioShack, you can purchase them from RadioShack.com, model 278-1156.*
- Insulated wire (about 25-cm)
- Cardboard (at least as large as the jar opening)
- 3 brand new D batteries
- Wire cutters and strippers
- 2 Paper clips
- Nail (slightly thicker than the insulated wire)
- Adhesive tape

## Instructions

1. Cut a piece of cardboard to just fit over the top of the jar.
2. Use the nail to punch 2 holes in the cardboard, about 1.5-cm apart and near the center.
3. Cut two pieces of insulated wire, 12.5-cm long.
4. Strip 2.5-cm of insulation from each end of both wires.

5. Bend one end of each wire into a small hook and push the other end of each wire through one of the holes in the cardboard lid, so that the hook ends hang about halfway into the jar.
6. Bend the wires on top of the lid and tape them down, making sure they don't touch each other or any other conducting surface.
7. Cut a 5-cm piece of picture hanging wire and separate it into individual thin wires (or cut a 5-cm piece of nichrome wire).
8. Twist 2 or 3 of the thin wires from the picture hanging wire together to form a filament, and bend it around the hooks that will hang inside the jar (or bend a single strand of nichrome wire around the hooks).
9. Replace the lid and tape it onto the jar.
10. Tape the three D batteries together, positive end to negative end.
11. Tape a paper clip to each end of the battery system.
12. Connect an alligator clip wire from one of the paper clips to the end of one of the wires coming out of the jar.
13. Connect the other alligator clip wire from the free paperclip to the free wire coming out of the jar.
14. The filament should glow for a few seconds (or longer, if using nichrome wire) and then break.



## Troubleshooting

If the wire burns out too quickly, add another strand of picture hanging wire to the filament or use one less battery in your circuit. If you have trouble getting the wire to glow, check the connections between the batteries and between the filament and the insulated wires.

## Discussion questions

- What makes the wire glow?
- Why do wires in electric circuits get warm? What kinds of precautions do we take to make sure this is not dangerous?
- How are light bulbs you buy in a store different from this homemade one?
- How do you think changing the thickness of wire might affect the light produced?

## Discussion

The filament glows because the thin wire has a high electrical resistance, meaning that it is difficult for electrons to travel through it. Because there is a high current flowing through the wire and the wire has high resistance, the energy is released as light and heat. Filaments glow and burn while thicker wire only heats up slightly because thin wire has this higher resistance (traffic flows faster, or meets with less resistance, on a wider road with more lanes).

When the wire burns out the circuit is broken and the filament no longer glows. If you look carefully at the filament of a burned out light bulb you can sometimes find the break; you can also shake the bulb and hear the broken pieces rattling.

Commercial light bulbs give off brighter light than the homemade bulb because their filaments are made of tungsten instead of the iron (or nichrome) wire we used. Tungsten's high melting temperature makes it an ideal filament, since other metals melt before getting hot enough to give off the white light we use to light our homes. They are able to stay lit for many hours because the glass bulbs either have no air in them, or are filled with a dilute gas other than oxygen, since oxygen speeds up the burning process.

### Suggested resources

"Fluorescent Lamp." Wikipedia. [http://en.wikipedia.org/wiki/Fluorescent\\_light](http://en.wikipedia.org/wiki/Fluorescent_light)  
*This site explains how a fluorescent bulb works.*

Harris, Tom. "How Light Bulbs Work." How Stuff Works.  
<http://home.howstuffworks.com/light-bulb2.htm>  
*This site has a detailed explanation of the parts of a light bulb and how they work together to produce light. After clicking "Next" a couple of times, there are links to more information on light bulbs.*

"Incandescent Light Bulb." Wikipedia. [http://en.wikipedia.org/wiki/Incandescent\\_light\\_bulb](http://en.wikipedia.org/wiki/Incandescent_light_bulb)  
*This site has more information on incandescent and halogen bulbs.*

### Bibliography

"Edison Invents: Make a Light Bulb." Smithsonian's Lemelson Center.  
[http://invention.smithsonian.org/centerpieces/edison/000\\_lightbulb\\_01.asp](http://invention.smithsonian.org/centerpieces/edison/000_lightbulb_01.asp)

Reuben, Gabriel. *Electricity Experiments for Children*. New York: Dover Publications, Inc, 1960. Page 42.

"Short Circuit: What Happens When You Blow a Fuse?" Exploratorium Snacks.  
[http://www.exploratorium.edu/snacks/short\\_circuit.html](http://www.exploratorium.edu/snacks/short_circuit.html)