The Brightest Bulbs on the Christmas BEAM

Mason Earhart, Meisen Wang | Fall 2023

Field(s) of Interest: Physics, Chemistry, etc.

Brief Overview (1-3 sentences):
In this lesson plan, mentees will be introduced to electricity and its many uses. Mentees will visualize how charge is transported through a circuit via current, as well as see potential uses for electricity in the sciences.

Agenda:

- Introduction (5 min)
- Module 1: Free of Charge (10 min)
- Module 2: Ohm Sweet Ohm (15 min)
- Module 3: You've Got Potential! (25 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:	**Mentor Development Goals:** **Written by MD**
➔ Charge ➔ Electricity ➔ Circuit ➔ Current ➔ Chemistry ➔ Chemical Reaction	➔ **Getting Mentees Engaged** ➔ **Teamwork Makes the Dream Work** ➔ **Keeping it Balanced**

Background for Mentors

Module 1

1. **Charge**
2. **Repulsion**
3. **Attraction**
4. **Electricity**
5. **Electron**

Free of Charge

Electric **charge** is a fundamental property of matter responsible for the electromagnetic interactions between particles. Charges can be positive, negative, or neutral. The origin of charges comes from the atom, where the positive charge comes from the protons of the nucleus, and the negative charges stem from the **electrons** that orbit the nucleus.

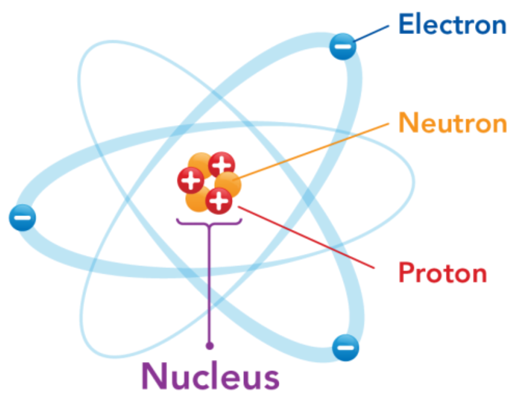


Figure 1: simplified diagram of an atom

Charge is defined solely from the interactions that a particle has with other charged particles. There is no inherent meaning behind a negative charge, other than it repels other negative charges and attracts positive ones. **Repulsion** occurs between two similar charges, which push each other away. Conversely, **attraction** occurs between two dissimilar charges, which pull each other closer. It is through the application of these repulsive and attractive forces that we can make charge move. An easy to understand example consists of a battery in a circuit. A battery has a positive and negative end, where the negative charge is repelled from the negative end and attracted to the positive end. The movement of the charge through the wire as it is repelled/attracted is what we call **electricity**.

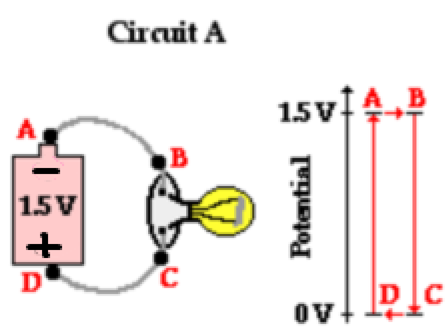


Figure 2: Simple circuit showing how the attraction/repulsion makes charge move

Module 2

- Circuit
- Current
- Work
- Series (advanced)
- Parallel (advanced)

Ohm Sweet Ohm

A **circuit** is a closed loop through which electric **current** can flow.It's the fundamental concept behind the functioning of most electrical devices and systems. Circuits are essential for transmitting and controlling electricity to power various devices, from simple household appliances to complex electronic gadgets.

A basic circuit typically consists of the following components:

- Power Source: This provides a **voltage** and is where the electrical energy originates.
- Conductors: These are materials, usually metal wires, that allow electric current to flow through them easily.
- Load or Device: The load is the part of the circuit that uses electrical energy and provides **resistance**. It could be a light bulb, motor, computer, or any other electrical device that performs a specific function. The current does **work** as it travels through the load and for example, lights a lightbulb.
- Switches: Switches can be used to open or close a circuit, controlling the flow of current.

The flow of current through a circuit is described by **Ohm's Law**, *V=IR*, where V=voltage, I=current, and R=resistance.

Circuits can be wired in **series** or in **parallel**. In series, the resistance of all devices adds up, and the failure of one device opens the entire circuit loop. In parallel, the current is "split" between the different paths, while it is not in series.

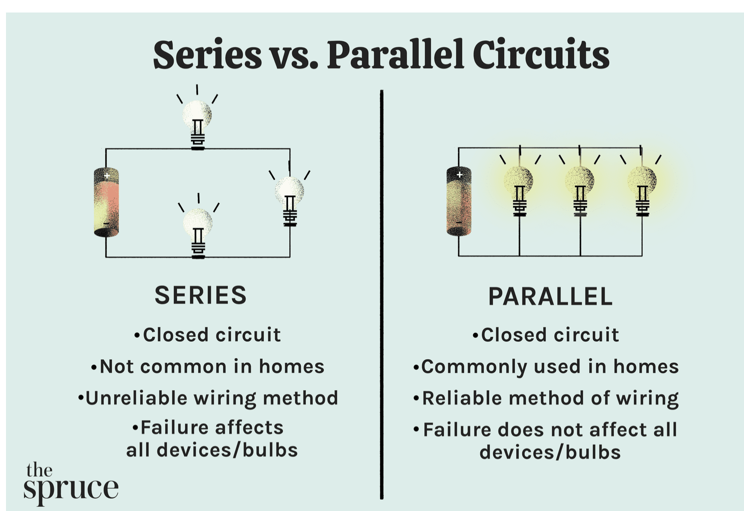


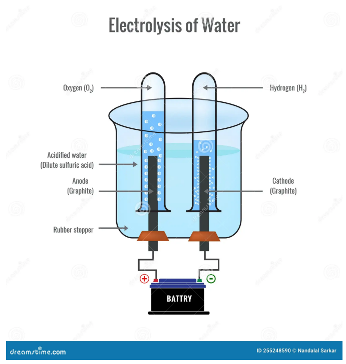
Figure 3: Series vs. Parallel circuit wiring

Module 3

- **Chemical Reaction**
- **Electrolyte**
- **Electrolysis**

You've Got Potential!

A **chemical reaction** is a process through which matter (materials) of one kind are converted into matter of another kind. A common example seen in everyday life is the rusting of iron. This reaction is one that occurs on its own, and thus is known as spontaneous. This is due to the products of this reaction, in this case rust, being lower in energy than its reactants, iron and oxygen. Other reactions are nonspontaneous, meaning that it does not occur on its own. This is because the products are higher in energy than the reactants. As a result, significant energy is required to drive this type of reaction. **Electrolysis** is the splitting of water into oxygen and hydrogen using an electric current. Oxygen and hydrogen are both gasses with high energy, meaning that they like to react to form water. Thus, in order to get these gasses back from water, energy is required, which in the case of electrolysis is delivered via the electric current.



- Cathode reaction:

$$2H_2O_{(l)} + 2e^- \longrightarrow H_{2(g)} + 2OH_{(aq}$$

- Anode reaction:

$$2H_2O_{(l)} \longrightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$$

Figure 4. Reaction Diagram

To conduct electricity, **electrolytes** must be dissolved in the water. These are ions dissolved in solution that carry a charge in place of an electron. This disproves the idea that water is electrically conducting, as it is actually the ions dissolved in the water that do the conducting. This is why it is required to have an electrolytic solution to perform an electrolysis reaction, as otherwise the circuit could not be completed through the water, and no decomposition would occur.

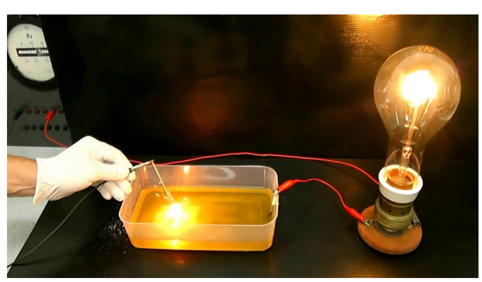


Figure 5:. Electricity conducted through water

Introduction

<table>
<tr>
<td>
Concepts to Introduce

Charge
Charge is an inherent property of all matter, but is only defined through the ways that it interacts with other charges

Electric potential
Using a charge difference, we can attract electrons around a circuit and thus current is created

Electrochemistry
By harnessing the power of a potential, we can use electrons/charges to make a chemical reaction happen that wouldn’t otherwise occur

</td>
<td>
Questions to Pique Interest

What are some objects in your house or in the room that are operated by electricity?
How can I flip a switch and suddenly the room fills up with light?
Why do we need to avoid downed power lines?
Have you ever been shocked by playground equipment? What causes that?
Why is it that a balloon can make our hair stand on its end?

</td>
</tr>
<tr>
<td>
Scientists, Current and Past Events

Benjamin Franklin, one of the founding fathers, is credited with the discovery that lightning is electrical after flying a kite with a key attached to it in the middle of a thunderstorm. A shocking find!
Though Thomas Edison is credited with inventing the lightbulb, he was one of many trying to improve upon an existing, impractical, design!
We are constantly trying to find new ways to generate electricity. Nuclear fusion is providing one promising avenue to do so: US scientists repeat fusion ignition breakthrough
Many see electric vehicles being the future of transportation, with improvements such as these being made every day

</td>
<td>
Careers and Applications

Electrical engineer - these people utilize their knowledge of electricity and circuits to design every electrical device that we see in our daily lives!
Physicist/Chemist - in order to understand how the scientific devices they use in the lab work and how they should be read, it is important for these scientists to have a working knowledge of electricity.
Technicians - the job of these people is to make sure that the devices that run on electricity continue to run smoothly, and address any issues that may arise from them.

</td>
</tr>
</table>

Module 1: Free of Charge

In this module, mentors will perform the flying tinsel demo, where a charged pie tin will be used to polarize a piece of tinsel and allow it to fly. This will demonstrate to mentors how like charges repel one another, even against the force of gravity! **This module will be a demo**

<table>
<tr>
<td>

Teaching Goals

1. **Charge:** A property of matter that is described by how the material responds (attraction/repulsion) to other charged materials
2. **Repulsion:** The tendency of one charge to push a like charge away
3. **Attraction**: The tendency of one charge to pull an unlike charge closer
4. **Electricity:** The movement of negative charge from a negative area to a more positive one
5. **Electron:** A subatomic particle that orbits the nucleus of the atom and carries a negative charge; creates electricity!

MD Goals:

1. **Getting Mentees Engaged -** Sometimes it can be difficult to get mentees to pay attention to demos, especially for a high-energy class. Rather than having all mentors stand at the front of the classroom, have mentors stationed around the classroom to remind any distracted mentees to focus their attention on the demo being performed.

</td>
<td>

Materials

- Per site:
  - 1 pvc “wand”
  - Wool cloth
  - Tinsel

</td>
</tr>
</table>

Different Methods for Teaching

1. **Opposites attract, likes repel:** While they’re different forces by concept, this is similar to how magnets also attract and repel, based on their poles. For younger sites that may not understand positive/negative, it may be helpful to use “opposite” colors.
2. **Make it visual:** Try to walk mentees through where the charge is going during the demonstration. We can’t see it, but if we know where it is, we can help mentees visualize what is happening.

Procedure

1. First, rub the wool up and down the side of the wand that is furthest from where you are holding it. You want to mitigate the migration of any charge away from the wand into your hand.
2. You now have a magic wand! Walk around the room and use it to make the hair on mentees' heads stand up
3. Give each table/group of mentees a piece of tinsel, and use your magic wand to make the tinsel dance or attack the wand. Have fun with it!

Figure 6: *Charge the magic wand on the end away from your hand*

Figure 7: *Grabbing the tinsel with the wand*

Figure 8: *Grab dat tinsel* 😎

Classroom Notes

If there is time, give mentees an opportunity to see how the process works! Let them try charging the wand and messing around with the tinsel/hair.

Module 2: Ohm Sweet Ohm

Mentees will build a working circuit. As current travels through the circuit, it visibly powers lightbulb(s). If using series or parallel wiring, mentees can again visualize the level of current through various lightbulbs.

<table>
<tr>
<td>

Teaching Goals

List and explain/define the 1-3 main concepts you want to focus on *for this specific module*. For example...

1. **Circuit:** the complete path of an electric current including the source of electric energy
2. **Current:** the rate of flow of electrons
3. **Work:** measure of energy transfer
4. **Series:** all components are connected end-to-end to form a single path for current flow
5. **Parallel**: all components are connected across each other with exactly two electrically common nodes with the same voltage across each component

---

MD Goals

- **Team Work Makes the Dream Work**

For experimental setups with multiple parts, students might not be able to effectively work together, especially since they might not be familiar with circuits. Try to assign different roles to mentees to ensure everyone gets a chance to contribute to building the circuit.

</td>
<td>

Materials

- Per mentor:
  - 3-4 alligator clip wires
  - 2 1.5V batteries
  - 2 light bulbs

</td>
</tr>
</table>

Different Methods for Teaching

1. **Current:** The flow of electrons in a circuit can power various devices like a lightbulb, motor, etc. Mentees can also think of the current like the flow of water through a watermill. The water can split into multiple streams (parallel) or stay in one large stream (series). If one stream was blocked, the entire river would still flow through the osther streams in parallel, but completely stop in series.
2. **Work:** Mentees are doing work when they lift a heavy box off the floor. The current does a similar sort of "work" when they flow through a lightbulb and light it up.

Procedure

4. Mentees should split up into groups of about 4 with one mentor per group.
5. Each group should receive 3-4 alligator clip wires, 2 batteries, and 2 lightbulbs.
6. Half of the class should build their circuit in series (Figure 8). The other half should build their circuit in parallel (Figure 9).
7. Mentees should do a “gallery walk” to compare the 2 different builds in terms of wiring, bulb brightness.
8. Remove one lightbulb from each circuit. Does the other lightbulb still light up?
9. Make sure that there is no path from one end of the battery to the other end that does not pass through a lightbulb. This will cause a short circuit!

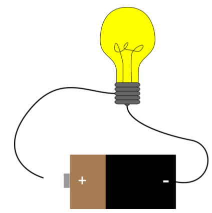


Figure 7: simple circuit with 1 lightbulb

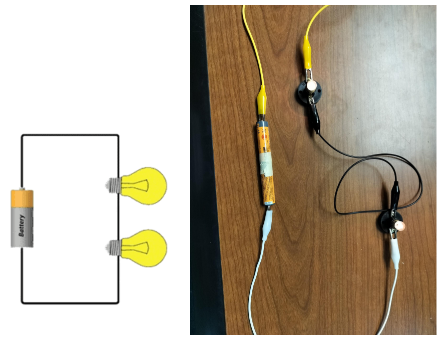


Figure 8: *2 lightbulbs in series*

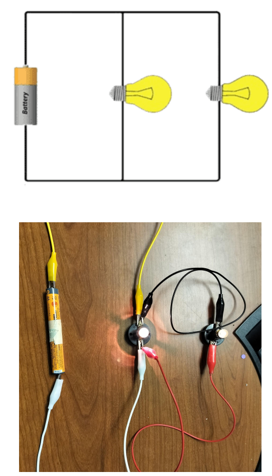


Figure 9: 2 lightbulbs in parallel

Module 3: You've Got Potential!

During this module, mentees will get to see electricity used in the generation of hydrogen and oxygen gasses from water! **This module will be an instructed build**

Teaching Goals

1. **Chemical Reaction:** A process through which one or more chemical(s)/material(s) are converted into another with the addition of energy
2. **Electrolysis:** A chemical reaction where electricity is used to split water into oxygen and hydrogen
3. **Electrolyte:** An ion that, when dissolved in solution, is able to carry charge

---

MD Goals

- **Keeping it Balanced**

Even though Mentors will have to do most of the setup for the demo, be sure to encourage participation from mentees! This can be through asking questions about the functionality of different parts, prompting predictions, or asking mentees to help set up

Materials

- Per site (4 groups):
  - 4 cups
  - 4 cardboard squares
  - 4 9-volt batteries
  - 8 pencils w/o erasers attached
  - 8 alligator clip wires
  - Water
  - Salt

Different Methods for Teaching

1. **Think like a wire:** In order to understand why this reaction is able to take place, it might be useful to compare the electrolyte solution to the wires in module 2. In both cases, there is a material (copper in a wire, electrolyte in solution) that can easily carry a charge, which allows for the electricity to do work and drive the reaction.
2. **Visualize the reaction:** It may be useful to model the reaction for the students, either with mentors or with the mentees. Three mentors/mentees can hold hands, symbolizing a water molecule. A fourth mentor/mentee can act as the electrolyte, and give a charge to one of the molecule mentors/mentees, splitting the molecule and creating the gas.

Procedure

10. First, if both ends of the pencils are not already sharpened, sharpen the pencils. It is important that there is exposed graphite on each end of the pencil.
11. Next, add water and salt to the jar.
12. Stick the pencils through the cardboard piece

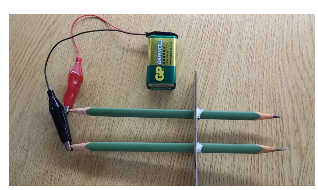


Figure 10: *Double-sided pencils attached to the battery*

so that they will remain still in the water.

13. Next, use masking tape to connect one end of each wire to the pencils, so that each pencil has its own unique wire.
14. Then, **carefully** attach the other ends of the wires to the terminals of the battery and hold them using the tape.
15. The electrolysis should begin almost immediately, so students should be watching the ends of the electrodes as the mentor is attaching the final wire to see the reaction.

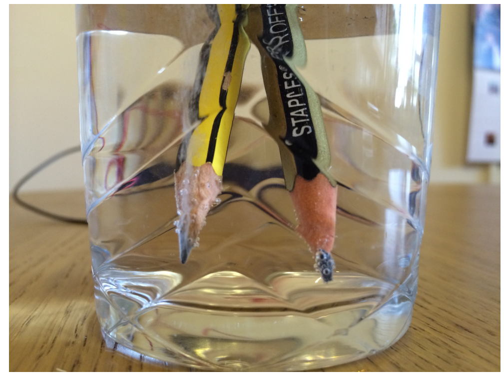


Figure 11: *Splitting water on the ends of the pencils!*

Classroom Notes

This build may be a bit difficult for rowdier sites, so focus on engaging them with the build as much as possible. Ask the students what they think each component is for. If they don't know, give them facts about the setup that could guide them to the answer. For example, if they don't know why we need to add salt, you could mention an interesting fact someone told you about seawater, and how it conducts electricity better than normal water. This will get students thinking about the reaction and keep them engaged in the material.

Conclusion

Electricity may seem like magic, but at the end of the day it's simply electrons at work! We can see how electricity can be utilized to do a great number of things, but there are many other things that we couldn't even hope to begin to cover in this lesson. But now you have an understanding of what it means to live in an electrified world, so use what you have learned today to try and figure out how other devices in your life function!

References

- Flying Tinsel, Exploratorium. https://www.exploratorium.edu/snacks/flying-tinsel
- Series and Parallel Circuits, Sparkfun. https://learn.sparkfun.com/tutorials/series-and-parallel-circuits/all
- Electrolysis, Horizon Educational. https://www.horizoneducational.com/electrolysis/t1323?currency=usd

Summary Materials Table

Material	**Amount per Site**	**Expected $$**	**Vendor (or online link)**
Extremely Specific Item Name	1 per student		Amazon

Pie tin			
Styrofoam plate			
Styrofoam cup			
Wool cloth			
Tape			
Tinsel			
Alligator clip wires			
9-volt battery			
Light bulbs			
Cups			
Pencils			
Distilled water			
Kosher salt			
(Wires?)			