INNOVATION AT PLAY

AFTERSCHOOL ACTIVITY

POCKET CHANGE TO POWER

OBJECTIVES

Students will be able to:

- Understand how electrochemical cells convert chemical energy to electrical energy.
- Design voltaic cells to light different LED colors.

OVERVIEW

As we move into Industry 4.0, more and more components will require power with flexibility in order to be used in spaces without constant electricity. Drawing on an understanding of the different types of energy, students will explore electrochemical cells and the power they can provide. The students will design and construct a voltaic cell that creates enough power to light a red LED. Red LEDs require lower minimum voltages to light when compared to blue and white LEDs. Even when thinking of the electric-powered tools and items we use daily, the power required is different. Challenging the students with this in mind, they will have to determine how to adjust their voltaic cell design to light different LED colors with different minimum voltage requirements.

MATERIALS

- 10 Pennies
- 10 Nickels
- Aluminum Foil
- Dish Soap
- Scissors
- Construction Paper
- Paper Towel
- Pen/Pencil
- Small Bowl or Cup
- Vinegar
- Salt
- Insulated Test Leads with Alligator Clips
- LEDs (Red is required but any other colors can also be used)

OPTIONAL MATERIALS

- Multimeter with Leads
- Tweezers

ACTIVITY PLAN

- First, lead a discussion:
    - Ask students what they use on a daily basis that requires electricity.
        - Examples might include cell phones, computers, cars, trains, watches, and calculators.
    - Ask students which of these operate on a battery, and which have rechargeable batteries.
        - Cell phones and computers utilize rechargeable batteries, but smaller items like watches and calculators utilize alkaline batteries.
    - Ask students what the benefits are to having electronics run on battery power rather than direct power from an outlet.
        - Answers might include that it allows for use anywhere (not restricted to places with outlet locations), it can be used in emergencies when outlets do not work, etc.
    - Explain to students that as our world becomes more connected, batteries become more and more essential. The significance of batteries lies in their ability to overcome the constraints of space and time by continuously providing or replenishing energy when it is depleted. Consider, for example, the case of an AI robot that becomes ineffective if it can only operate for less than 10 minutes without being connected to a power source. To enable AI robots to engage in continuous self-study using vast datasets, they must remain operational 24/7. To ensure that robots, drones, wearable devices, and similar technologies can move freely and assist us effectively, they must be capable of sustaining power for extended periods without relying on an electrical outlet. Ultimately, the solution to this challenge lies in energy storage devices, commonly known as batteries. The realization of a hyperconnected society, where the limitations of time and space are eliminated, hinges on battery technologies that offer substantial capacity and high efficiency.

> The Future of Batteries
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> **The world needs more power, preferably in a form that's clean and renewable. Our energy-storage strategies are currently shaped by lithium-ion batteries—at the cutting edge of such technology—but what can we look forward to in years to come?**

- Next, watch: https://www.youtube.com/watch?v=PPp3E8rFiMU
    - Explain to students that alkaline (non-rechargeable) batteries rely on chemical interactions to create electricity. It relies on a material that wants to release electrons, the anode, and a material that wants to accept electrons, the cathode. You will also hear these terms in the video. The manganese dioxide, which was closer to the steel pan of the battery, loses electrons and therefore acts as the anode while the zinc powder, closer to the center of the battery, gains electrons and therefore acts as the cathode. The reaction also relies on the paper that separates the two. This part is soaked in potassium hydroxide to assist in the flow of electrons.
- Model it: https://teachchemistry.org/classroom-resources/voltaic-cells
    - Direct students to select zinc for the left beaker, magnesium in the right beaker, then to click the switch under the volt reading to start the simulation.

- Direct students to look at the molecular scale depiction in the right beaker. Ask them what they see.
  - Magnesium atoms are coming off as ions (Mg^{2+}) and the electrons are traveling up the piece of metal toward the wire.
- Direct students to look at the molecular scale depiction in the left beaker. Ask them what they see.
  - Electrons traveling down the piece of metal and a zinc ion (Zn^{2+}), being attracted to the electrons, taking those electrons and binding to the metal.
- Ask students what would happen if there were no more magnesium atoms to donate electrons for this process.
  - There would be no electricity.
- Point out to students that this explains why alkaline batteries are only good for a certain period. The materials are degrading and are losing their capability to produce the electrons needed to provide current.
- Explain to students that with this understanding of electrochemical batteries, they will be challenged to create their own batteries out of coins!

How do rechargable batteries work? They are made of materials that can move electrons and ions in either direction through the circuit and electrolyte. When the electrons move from the cathode to the anode, they increase the chemical potential energy, thus charging the battery. When they move the other direction, they convert this chemical potential energy to electricity in the circuit and discharge the battery.

- Goal: Create a voltaic battery to power different LEDs.
  - Directions
    1. Gather materials.
    2. Wash pennies and nickels with dish soap and water and then dry them. This is to remove dirt and grime for the coin's surface.
    3. In a small bowl or cup, mix together ¼ cup of vinegar and 1 tbsp of salt. Stir well.
    4. With scissors, cut a strip of aluminum foil, 20cm x 80cm. Fold lengthwise three times. Aluminum foil is a good electrical conductor and will be in contact with the bottom of our battery to aid in connecting our LED and/or multimeter leads.
    5. Trace a penny 10 separate times onto the construction paper and cut out the circles with scissors. Make sure the 10 circles are slightly smaller than the pennies. This will prevent liquid from dripping over the edges of the coins, which can cause a short circuit.
    6. Place a dry paper towel on a table as the workstation.
    7. Place the aluminum strip in the middle of the workstation.
    8. On one end of the aluminum strip, place one penny.
    9. With fingers or tweezers (optional), soak a construction paper circle in the vinegar-salt solution. The paper should be wet throughout but not dripping.
       The circle can be dabbed on the paper towel to remove excess liquid.
    10. Place the vinegar-soaked paper on top of the penny.
    11. Add a nickel on top of the paper. This is now a tiny battery.

12. Take one test lead and use the alligator clip to connect it to the short leg of a red LED. Connect the opposite end of that test lead to the aluminum strip with the battery.
13. Take another test lead and use the alligator clip to connect it to the long leg of the red LED.
14. Gently, but firmly, press the metal clip of the opposite end of the second test lead to the nickel at the top of the battery.
    - If using multimeters, measure the direct current voltage by placing one lead on the aluminum foil strip and one lead on the top of the battery.

The copper surface of the penny is our cathode, the vinegar is our electrolyte, and the nickel surface (made mostly of nickel) is our anode.

- Have students describe their observation of the LED. Is it lit, flickering, or dim?
  - Students should see no light.
- Explain to students that what we have created with our penny, paper, and nickel layers is one voltaic cell. Batteries can consist of one or more cells to generate the power needed.

15. Construct another voltaic cell (penny, vinegar-soaked paper, and nickel) and place it directly on top of the first with the nickel on top.
16. Place the metal clip of test lead from the long leg to the top of the battery and make observations.
    - If using multimeters, take another direct voltage measurement. What happens to the voltage?The voltage is additive since they are connected in a series. The reaction of one voltaic cell should provide about 0.4V but with ten cells connected in series we can get over 3V.

Watch this video to see how this concept applies to 9V batteries.

- Pause students and ask them to predict the number of cells needed to light their red LED.

17. Continue adding cells until the LED lights.

- Once students have created enough voltage for their red LED, challenge students to adjust the voltage for another colored LED. Have students pick a color to light and ask them to predict if it will need more or less voltage than the red LED.

18. Unclip the red LED from the test leads and replace it with an LED of another color.
19. Adjust the number of cells, add more, or take some away, to light the new color.

- Ask students why each LED requires a different voltage.
  - Explain that the different colors of LEDs are made from different semiconductor elements and each semiconductor element has its own activation voltage. Shorter wavelengths of light are made from higher energy photons. Red is longer wavelength/lower energy than yellow than green than blue which is shorter wavelength/higher energy. To make a photon, you need to get an electron from the material to a higher valence shell. The

electron doesn't like to stay there, so it will fall back down to its rest shell. When it falls, if we got the material mix right, it will kick out a photon. We provide energy to raise the electron from its normal (rest) state. The higher we raise it, the more energy we have that can be released in the form of a photon when it falls back down. Voltage is a measure of energy. So, to get the electron to rise up to the higher state, we apply voltage. The higher the voltage means the more energy released. Red (lower energy photons) LEDs need less voltage than yellow than green than blue (higher energy photon) LEDs.