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| **Lesson Title: Introduction to Electrochemistry** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **1** |
| **Activity Title: How does a battery work?** |

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| **Estimated Lesson Duration:** | **10 class periods (80 minutes each)** |
| **Estimated Activity Duration:** | **2 class periods (80 minutes each)** |

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| **Setting:** | **Science classroom** |

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| **Activity Objectives:** |

**W**e **W**ill…

* Design and construct simple motorized vehicle models using the most basic components to obtain movement
* Explain how electric current is formed within a battery and how powers a simple motor.
* Describe the energy conversions that take place in the model car’s operation.

**I**n **O**rder **T**o…

* Calculate the work energy produced by the movement of the designed vehicle over a specific distance.
* Observe, calculate and compare the velocities of the designed vehicles to others by measuring the time elapse to travel a certain distance.
* Calculate and compare the power of your vehicle’s motor system in comparison to other vehicles.

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| **Activity Guiding Questions:** |

* What components are needed to produce a successful circuit?
* How are these components arranged to make the circuit successful?
* What types of energy do we use everyday?
* What type of energy transformation took place?
* What role do the copper sulfate, sodium sulfate, magnesium, and water play in the circuit?
* How does the design (car body) support the weight of motor, battery (ies), and wires that will be added? How will this affect the car's speed?
* Which type of motor and/or battery would be most effective and efficient for my vehicle?
* What kind of benefit/impairments would be added to my vehicle if additional batteries and/or motors were added? (Think about question 1 again). What additional materials would be needed?
* What other components (like body material, wheels, etc.) could be added in addition to or in place of provided base materials, to allow for creativity and/or design improvement?
* What will our Unit Challenge be?
* How will that Challenge capitalize on our understanding of electrochemistry?

| **Next Generation Science Standards (NGSS)** | |
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| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☒ Developing and using models | ☐ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☒ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☒ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☐ Obtaining, evaluating, and communicating information |  |

| **Ohio’s New Learning Standards for Science (ONLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| ☐ Demonstrating Science Knowledge **(D)** |
| ☐ Interpreting and Communicating Science Concepts **(C)** |
| ☐ Recalling Accurate Science **(R)** |

| **Common Core State Standards -- Mathematics (CCSS)** | |
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| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, ONLS and/or CCSS):** |

LO = Advanced Placement® Chemistry Learning Objective

SP = Advanced Placement® Science Practice

SEP = NGSS Science and Engineering Practices

LO 3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer.

SP 6.1 The student can justify claims with evidence.

SEP 7: Engaging in argument from evidence

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

**This activity was inspired by a lesson found on** [**www.teachengineering.org**](http://www.teachengineering.org)

(<https://www.teachengineering.org/view_activity.php?url=collection/uoh_/activities/uoh_electrons/uoh_electrons_activity1.xml>)

**Links/Websites:**

# Batteries: A Big Idea That Turned on the World: <https://www.youtube.com/watch?v=UxlJQ2ZLMIs>

# Build a Circuit Simulator: <http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc>

* 3-Part Galvanic Cell Activity: DOI: 10.1021/ed500726y
* Hands-On Activity: From Electrons to Electric Motors: (see teach engineering URL above)

**PowerPoints:**

* Day 1 – The Hook
* Day 2 – The Hook, part 2

**“Hands-on Activity…” Supplies:**

To share with the entire class:

* double-sided tape
* electrical and/or regular tape
* glue gun(s) with glue sticks
* rulers
* construction paper
* markers
* scissors
* computer with Internet access and classroom projector, for a teacher demo
* a toy car or a constructed model, for a teacher demo

**3-Part Galvanic Cell Supplies:**

For each group:

* magnesium
* filter paper
* copper sulfate
* sodium sulfate
* LED diode

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| **Teacher Advance Preparation:** |

**Build a Circuit Simulator:**

Need to reserve class laptop cart for this activity and install the plug-in for phet / test to make sure the activity works properly on each device.

**3-Part Galvanic Cell:**

To make the cell components, one piece of filter paper is soaked with sodium sulfate solution and another with copper sulfate solution and then dried. The dried filter papers can be cut into pieces between 1/2 and 1 cm2 . The third part of the cell is a piece of magnesium ribbon. The sodium sulfate paper piece is used to make the ion bridge and should be larger than the piece of copper sulfate paper to avoid inadvertent contact between the galvanic cell components. The positive terminal of the LED used for testing the cell should be covered with an inert, conductive material to avoid a reaction between the terminal metal and the copper sulfate. An easy way of coating the terminal is using conductive glue or tape. We prefer conductive epoxy glue with silver, but other types have also shown to work well.

**Hands-On Activity: From Electrons to Electric Motors:**

<https://www.teachengineering.org/view_activity.php?url=collection/uoh_/activities/uoh_electrons/uoh_electrons_activity1.xml>

Build a prototype electric model car so as to: 1) have the ability to foresee any possible limitations or construction problems with the supplied materials, and 2) create a demonstration model to help students initiate the planning and construction of their own vehicles.

Unlimited ways exist to design and build model electrical vehicles. Below are some basic steps for how to build one. (Not all steps are shown by images.)

1. Cut out a rectangular piece of cardboard.
2. Glue or tape down (use mounting tape) the L-shaped shelf brackets to each corner, as shown in Figure 1.
3. Place a wooden dowel (stick) through the loops of the L-shaped brackets.
4. Put regular tape around each end of the wooden dowel, until the wheels fit snuggly around the wooden dowel, and glue the edges.
5. On the drive-train dowel (the one that will be connected to the motor), wrap the middle with tape and place a spool in the middle of the dowel.
6. Place a rubber band around the spool.
7. Cut out a square or rectangle in the cardboard, above the spool axle, about 1-2 inches back.
8. Position your motor on top of the cardboard base.
9. Pull the rubber band through the opening, place it around the needle, and pull back far enough so the rubber band is tight. (The power-train mechanism shown in Figure 3 is a belt system. Alternative ideas: Attach gears to the motor and axles to turn the wheels, or attach a fan-blade to the motor, to create a wind-propelled vehicle.
10. Glue or tape down the motor.
11. Glue or tape down the battery (or batteries). (Note: If using batteries such as D or C cells, then create electrodes for the "+"/ "-"terminals. Use small pieces from two different metals, like aluminum and copper, and tape the copper to the "+" terminal; aluminum to the "-"terminal.)
12. Place alligator clips on each end of the battery to each prong on the motor.
13. If everything is set up correctly, the car should move!

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| **Activity Procedures:** |

**Day One:**

1. Warm-up activity:
   1. How does electricity work?
   2. What type of material is within the electrical cords that allows electricity to flow through it?

The questions, above, will be used to engage students in the content of the unit and assess their understanding of the role of electrons in electricity, as well as the materials that facilitate electricity (conductor vs. insulator).

1. Students set up the day/unit in their interactive notebook, including table of contents, unit title page, and Day 1 content (Topic, Objective, Essential Question – print-out to maximize time)
2. Students, working in pairs, will receive a laptop and be guided to the URL for “Build a Circuit Simulator.” The purpose is to challenge the students to create an electrical circuit. Allow students to figure out the components needed in order to create a circuit that produces a successful circuit. Expect students to discover that the simplest means of creating a circuit is to have a power-supply [batteries], wires and a device, [in this case, a light]. This can all be used to review the concept of series [in which all wires are connected so that electricity can only flow from anode to cathode in one path] and parallel circuits [in which electricity can flow in multiple paths to reach the cathode].). Students will sketch a successful circuit in their interactive notebook (left page, p. 2) and answer the reflection questions:
   1. What components are needed to produce a successful circuit?
   2. How are these components arranged to make the circuit successful?
   3. How do parallel and series arrangements differ?
3. Introduce the 3-part Galvanic Cell to students by posing the following questions to the class:
   1. What types of energy do we use every day?
   2. What type of energy transformation took place?
4. Students, working in pairs, will receive a piece of magnesium metal and two pieces of soaked filter paper, one containing copper ions, one containing an inert salt solution as well as one LED diode. Prompted with a diagram of the layout, will assemble the cell, correctly, to light the LED. This will show students that Galvanic cells consist of three main parts: (1) the anode or negative electrode, (2) the cathode or positive electrode, and (3) the ionic conductor or the electrolyte that separates the electrodes. Students will sketch a successful cell in their interactive notebook (left page, p. 2) and answer the reflection questions:
   1. What types of energy do we use everyday?
   2. What type of energy transformation took place?
   3. What role do the copper sulfate, sodium sulfate, magnesium, and water play in the circuit?
   4. What form of energy is this?
5. Students, working individually, will be prompted to create Venn Diagram to compare/contrast the circuit and Galvanic cell. After 5-minutes, students will share out with the class to complete a whole class Venn Diagram on the SMART board. Students will be asked follow-up questions to provide evidence for the importance of their similarity or difference.
6. Demonstration of Work and Power: The teacher will use a toy car to demonstrate the concept of Work and Power. A section (race track) of the classroom floor will be taped off and measured by a student volunteer. The mass of the car will be measured by another student volunteer. The velocity of the car will be measured by a third student volunteer. The time it takes the carto reach the finish line will be measured by a fourth student volunteer. Using basic kinematics, the teacher and the class will determine the work that the motor put in to accelerate the car to the finish line:
   1. Acceleration = change in velocity / time
   2. Applied Force = mass of the car \* acceleration
   3. Work = Applied Force \* distance the car was moved by the motor

Using this model, students will get a working definition of “work.” This will be extended to the define the word, power: Power = Work / Time. Using the work calculated above, students how much power was used to move the car.

1. Following the work and power demo, students will be prompted with two problems to compare/contrast the amount of work and power calculated in the demo.
   1. A metro bus (4000 kg), accelerates from a stoplight at a rate of 4m/s2 in 30 seconds to reach its next stop, 500 meters away.
      1. How much work was done by the bus’s engine?
      2. How much power was used to operate the bus?
2. Students will be provided the “Keep it Moving” mini-challenge handout. The teacher will have students popcorn the instructions for the activity to have students to identify the challenge:

“You are going to be an engineer and design a motorized vehicle that meets the following design constraints: 1) You can only use the materials provided 2) You want your vehicle to be the lightest (lowest in weight) and fastest vehicle in the class 3) Your vehicle has to move at least 1 meter.”

1. Students will be guided through the EDP with the mini-challenge:
   1. Students will be required to brainstorm/chart out a design on chart paper before receiving their materials
   2. Students will utilize the materials/constraints to build their prototype.
   3. Students will test their prototype to assess its performance.
   4. Students will share out their performance on a class data table (SMART Board)
   5. Students will be asked to elaborate on performance data to get pinpoint successes and areas for revision.
   6. Students will tweak components of their design to improve their performance.
   7. Students will re-test and report out their redesign’s performance data on the class data table.
2. Exit Ticket: Students will, individually, complete the “Follow-up Questions” of the “Keeping it Moving” activity sheet.

**Day Two:**

1. Warm-up task: Students will be asked to read four statements about the video “**Batteries: A Big Idea That Turned on the World**”. Before showing the video ask the students to predict which of the four statements is the false/incorrect statement (activity is also known as “3 truths and a lie”). Show Video: “**Batteries: A Big Idea That Turned on the World:** [**https://www.youtube.com/watch?v=UxlJQ2ZLMIs**](https://www.youtube.com/watch?v=UxlJQ2ZLMIs)” YouTube video. Go over the statements and discuss the lie with the students.
2. Introduce the “Big Idea” of the unit to the students.
3. Instruct students to complete the following in their science notebooks on their own:

* Rewrite the big idea in your own words (looking for student interpretation)
* Write down at least 3 essential questions you have that could clarify the big idea for you.

1. Allow students time to brainstorm essential questions on their own. Then implement “Think Pair Share” activity. Be sure to record students ideas somewhere in the classroom where everyone can see them.

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

1. Warm-up: These two questions will determine the depth and breadth of students’ prior knowledge for the activity.
2. Building a Circuit: Student circuits, shown in the phet software will assess student understanding of a working circuit. Also, the student’s sketch including labels and annotations will elucidate the depth of student understanding.
3. Intro to 3-part Galvanic Cell: These two questions will determine the depth and breadth of students’ prior knowledge for the activity.
4. 3-part Galvanic Cell: Student Galvanic cells, with the lighting on their red LED will assess student understanding of a working cell. Also, the student’s sketch including labels and annotations will elucidate the depth of student understanding.
5. Venn Diagram: This activity will assess students’ ability to make a connection between a virtual circuit and a Galvanic cell. This will demonstrate if/when students naturally make the connection between the battery in the circuit and how the components of a Galvanic cell are serving as a battery.
6. Circulation during EDP: Students will be asked why they are making certain design decisions and prompted to justify their design decisions by employing what they know about electrons, electrical circuits, and transfer of energy forms.
7. Exit Ticket: the “Follow-up Questions” will assess each student’s understanding of the components to power their group’s car as well as their use of the EDP.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Students will have a unit assessment that will include 30 released multiple-choice items and 4 released free response items (2 long form and 2 short form questions). This will serve as a post-test to matching test items in the diagnostic for the course offered at the beginning of the school year.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

Auditory learners will benefit the discussion segments following each demo as well as the team talk time during the mini-challenge.

Kinestic/tactile learners will benefit from the hands-on nature of the Build a Circuit, 3-Part Galvanic Cell, and the mini-challenge activities.

Auditory and visual learners will benefit from the YouTube video that go along with the formative assessments (Warm-up for Day 2).

Students will special needs will be working in cooperative learning groups during the Day 1 activity to build the circuit, the cell and the battery powered-cardboard car.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

In hindsight, time could have been saved by Flipping Instruction for circuit content. Most students are familiar with the terminology from concepts of physics (9th grade). The Venn Diagram was a powerful way for students to draw connections between their prior knowledge and experiential knowledge with circuits and how they saw the 3-part cell operate. This content was a great set-up for the unit in terms of setting the stage for what was to come, but, in a time crunch and depending on the content strengths of the class, the circuit content could be delivered differently to meet time or content demands.