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| **Lesson Title : Access to Energy (Big Idea)** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **2** |
| **Activity Title: D-cell Battery Motor Build** |

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| **Estimated Lesson Duration:** | **1 week** |
| **Estimated Activity Duration:** | **3 days** |

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| **Setting:** | STEM workshop & computer lab |

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| **Activity Objectives:** |

* Students will assemble a simple motor using magnets, batteries, paper clips, and copper wire.
* Students will be able to diagram an electrochemical battery, complete with showing the path electrons would take in a closed circuit
* Students will be able to draw magnetic fields, describe the polarity of a magnet, and draw and label a motor diagram

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| **Activity Guiding Questions:** |

* How do magnets work? (What are magnetic fields?)
* How do wires work to conduct electricity?
* What are the necessary parts of a motor?
* How does a motor work?
* What is the relevance of insulation on copper wire?
* What is the relevance of metal coils in motor designs?

| **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 Learning Standards for Science (OLS)** |
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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)** |

| **Ohio’s Learning Standards for Math (OLS) and/or**  **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, OLS and/or CCSS):** |

HS-PS2-5: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

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| **Materials**: |

* Any toy with a working electric motor that moves around
* White boards and dry erase markers
* Iron filings
* Plastic petri dishes
* Parafilm or tape
* Magnets with labeled north/south poles for use with the iron filings
* Smaller magnets for use with the batteries
* D-cell batteries
* Rubber bands
* Paper clips
* Copper wire w/enamel coating for insulation
* Scissors to scrape the enamel off the ends

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| **Teacher Advance Preparation:** |

* Review [common misconceptions](http://www.physicsclassroom.com/class/circuits/Lesson-2/Common-Misconceptions-Regarding-Electric-Circuits) of students with regard to electricity. Build a working model of the motor for students to see and copy.
* A scattering of iron filings should be added to a petri dish and sealed with the parafilm (or tape). This method does not show the full magnetic fields – only spikes rising up from the bottom of the dish. It has the advantage, however, of being clean – no iron filings all over the desks and floor. It is preferable to have a plastic tote inside which you can tape a bar magnet and over which you can tape a sheet of white paper. After each demonstration, however, you will have to pour the iron filings into a side dish for re-use (or disposal). [Reflection: petri dishes worked much better than Tupperware totes, whose wall thickness had two negative consequences: first, it reduced the transparency of the container; second, it reduced the extent to which magnetic fields penetrated through the mass of iron filings.]
* Determine how much copper wire you intend to give each student (between 0.5 m and 1 m in length) and pre-cut them

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| **Activity Procedures:** |

1. Hook the class by turning on the demo toy and letting it run for a few seconds, then challenge the students to explain how that works.
2. Distribute white boards and markers and give students 3 minutes to diagram out their explanation.
3. Bring the class together to share their ideas.
4. Tell the class that they will repeat this exercise after they’ve had a chance to build their own working motors. [In practice, we ran out of time and I decided to have the students spend more effort working on the motors rather than discussing the results – too many students were struggling to get their motors to work and I did not want the discussion to fall flat with students dwelling on their frustrationsl]
5. Draw a simple diagram of an electrochemical battery. Distribute D-Cell batteries so students can visualize the structure as you describe its function.
6. Show the students a working D-cell motor. Have them take pictures of it while you distribute paper clips, copper wire, scissors, magnets and rubber bands to the students
7. Give the students time to build their own working motor replicas
8. While the students are working on their motors, walk around with a petri dish filled with iron filings. Use the north/south magnet to demonstrate magnetic fields. You may need to put the magnet beneath a sheet of white paper and pour the filings over the magnet to reveal the fields. Keep repeating this demonstration in small groups and task them with drawing diagrams of the magnet and the magnetic fields emanating from it. Ask them how the magnet interacts with the electrons to cause the coil in the motor to spin.
9. Once students have successfully built their own motors, bring out the electric toy again and challenge them to once again explain how it works, this time on a half-sheet of paper that they must turn in before leaving class.

**Formative Assessments:**

The white boarding is a formative assessment intendent to gain a sense for how familiar the students already are with electromagnetism, batteries, and motors.

During magnetic field demonstrations the teacher and/or TA should be assessing the ability of the students to explain what they are seeing in the demonstration.

Students will also demonstrate their understanding of content by being able to get their electric motors to spin – a major part of which involves positioning the magnet such that the fields will support rotary motion.

**Summative Assessments:**

At the conclusion of the activity, each student is required to submit a half-sheet of paper diagraming and explaining how an electric motor can move a toy around.

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| **Differentiation:** |

Students are given opportunities to interact **socially** to talk about electromagnetism. In addition, they have batteries, magnets, and copper wiring to **explore** the interactions facilitated by electromagnetism. **Demonstrations** and **small-group instruction** support student efforts to have abstract concepts explained with repetition. **Hands-on applications** of the concepts help students construct the knowledge on their own, and **drawing diagrams** of the results provides them with an additional visual cue for internalizing the content.

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| **Reflection:**  *After the activity is taught, reflect upon the successes of teaching this Activity in 5 or more sentences. Include a description of what Differentiation strategies worked and what should be changed – justify by presenting evidence and results.*  There was a surprising amount of frustration during this activity and it extended to two class sessions. By the end of the second class section, nearly all groups had managed to get their motors working, but it was a long and laborious process. I was impressed by the level of student engagement, however. Once they saw one team get their motor to work, hope of success was rekindled and students returned to their efforts with greater confidence of success. There are two parts of this build that complicate functionality: first, the position of the magnet must be just right to facilitate coil spin; second, the coil itself must be formed well enough that its spin is consistent and symmetrical. In future runnings, it will be important to get one team to achieve success early on and then provide that team with a second battery and more copper wire to see if they can build a bigger or a faster motor. Student motivation was the key factor both in engagement and in learning from the experience. I feel that I got lucky with my first running of this activity and students were able to propel themselves past frustrations and continue working. I would much rather have the activity better structured to nurture this persistence. |