INNOVATION AT PLAY

AFTER SCHOOL ACTIVITY

WIRELESS ELECTRIC TRAIN

OBJECTIVES

- Students will understand how an electrical current in motion creates a magnetic field and vice versa.
- Students will understand a direct, electrical connection is not required to have an electromagnetic field.
- Students will be able to design and build an electric train without the use of wires or a direct electrical connection.

Building upon their understanding of electromagnets, students will explore the idea of a homopolar motor without the need of an electrical connection. They will design and build a train track for their wireless electric train. Homopolar motors serve as a teaching tool on direct current motors that are used for any rotary electric motor. DC motors can be found in smaller electronics that have rotary movements like drills and toothbrushes, but also found conceptually in "synchronous ac" motors employed within electric vehicles. After designing their train tracks and successfully getting their train to traverse it, students will learn the connection between synchronous ac motors with the shift in the electric car market and how that can push into industry 4.0.

MATERIALS

Instructor Note: Although these materials will be used for the lesson, please complete the activity yourself to make sure all parts work. Batteries in particular can drain very fast in doing this activity.

- 14–18 gauge bare copper or aluminum wire. Enamel wire and insulated wire is possible but additional preparation work is required. Aluminum is also a little more difficult to make work.
    - In the event bare copper wire cannot be found, enamel coated wire may be burned off and then sanded down for smoothness. Likewise, insulated wire can be stripped off with a blade, scissors, wire cutters, or wire strippers. Please be sure that the wire is both bare and smooth.
- Scissors or wire cutters
- 3mm LED
- Iron rod or nail
- Dowel, thick marker, broom handle, etc. (diameter ideally 1mm larger than the magnets being used)
- AA or AAA Battery
- Strong disc magnets, ideally neodymium or rare earth (diameter must be larger than the battery being used)
    - At least two are required, one on each side of the battery. Ideally 6 small disc magnets would be used (3 on each side).

PROCEDURE

- In order to make sure our materials will work, review with students briefly about a direct circuit.
    - Have students attach a magnet at each end of the battery. To test if there is enough power for their train, create a circuit from the LED to the magnets on each end of the battery. If the LED lights up, the battery will be strong enough to power their train.
- Now that we know the battery works, have students put away the LED and circuit and grab their battery with the magnets attached. Have them shake the battery. If none of the magnets fall off, they are strong enough to move forward with their train design.
- Once the magnets have been approved for use, make sure that there is an even number of them on each side. We want the same polarity facing away from the magnet. In the layout below, North is facing away from the battery on each side.

  (N) [Magnet] (S) [Battery] (S) [Magnet] (N)

- Now that the train is built, students will need to begin building a basic train track. Using a thick marker, dowel rod, broom handle, etc. have students coil their wire as tight as possible to a length of about 6 inches or 15cm. They may use scissors or wire cutters to adjust the length of their coils if they wish.
- Once completed, have students test their train and track by pushing the train through the coil.
    - If their train does not move through the coil, there may be issues with the magnets possibly catching on the coils. Also, double check the polarity of the magnets on the battery ends, if any of them are incorrect the train will not move.
- Explain to students that the battery is providing an electric current and the magnets are creating a magnetic field. What the copper wire serves is a conductor. A complete circuit is created when the magnets touch the copper wire and now the electrons in the battery begin moving in the rotary motion due to the wire being coiled. The coils from this electromagnetic field are now pushing and pulling the magnets on the train, which is why the polarity of the magnets must be the same on each end of the battery.
- Once students have successfully made their train travel through their test track, have them design a train track of greater complexity. It could have hills to deal with or perhaps indoor and outdoor train track sections.
- Explain to students that the concepts used for their train are the basis of a direct current motor. This is the motor found in things like an electric toothbrush or electric drill. We used the coiling of the copper wire to create the rotation of the electromagnetic field, but electric motors now simply have a stationary part and a rotation part. Traditionally, dc motors are brushed, similar to our train. Brushed motors simply have a stationary part with permanent magnets while the rotating part has electromagnets. A "brush"

A sample of a complex train track can be seen here: https://youtu.be/Y1MDOerruDU?t=44

Did you see which part of our train was rotating? Was it the magnets or the battery? The part not moving is the stationary or stator, while the rotating part is the rotor.

creates physical contact with the rotor to transfer electricity, which then creates the electromagnetic field. As the rotor rotates, the electromagnetic field continuously flips its polarity resulting in a spinning motion.

  - Explain that students may have heard of a brushless motor, which is the same concept except the stationary part has the electromagnets and the rotating part has the permanent magnets. This concept is used for synchronous ac motors found inside electric vehicles.

- Explain to students that the concepts of motors found in everything around them have been in use since before 1900. The challenge right now is sustainability. Looking to the future in industry 4.0, we need to leverage our understanding of electric motors in order to create a more sustainable future.

This is the motor found in Tesla's Model 3. Check out the video below explaining how even newer, more efficient designs like the axial flux motors used by Mercedes and Ferrari, were already discovered and patented by Nikola Tesla back in 1889!

https://www.youtube.com/watch?v=esUb7Zy5Oio

Electric vehicles are still dependent on rare earth metals for permanent magnets, which is not sustainable. 17-year-old Robert Sansone invented the first sustainable electric vehicle motor.

https://www.youtube.com/watch?v=TYGdpJfpa3k