**Linear Motor Invention Kit**

**Sample Lesson Plan**

**Enduring Understanding**

Permanent magnets have polarity and can be used to move other permanent magnets and ferrous objects. A coil of wire connected to a source of electricity creates an electromagnet that functions as a non-permanent magnet

**Learning Objectives**

* Ask Questions about data to determine the factors that affect the strength of electric and magnetic forces. (MS-PS2-3, NGSS)
* Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field. (HS-PS2-5, NGSS)
* Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (MS.ETS1-4, NGSS)

**Learner Outcomes**

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| **Learners will know:** | **Learners will understand:** | **Learners will be able to:** |
| The definitions of the following key vocabulary words:   * Magnet * Electromagnet * Polarity * Battery * Solenoid * Frequency | * The polarity of one magnet can control a second magnet by attracting or repelling it. * Control magnets can be either electromagnets or permanent magnets. * Changing the polarity of a battery changes the polarity of a connected electromagnet. | * Use a linear motor to create motion. * Control a linear motor with an oscilloscope or microcontroller. |

**Activities** (Class 1)

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| **Time** | **Activity Type** | **Activity Description** | **Notes** |
| 5 min | Whole Class | Instructor leads a discussion in which learners attempt to answer the question “What makes things move?” and describe what they already know about motors. |  |
| 10 min | Whole Class | Instructor demonstrates a linear motor’s principles of operation using an assembled, working model. | Instructors should assemble their own models when preparing for this lesson. |
| 25 min | Small Group | Learners work together to assemble their own motor. |  |
| 10 min | Whole Group | Learners share challenges they encountered assembling the motor as well as ways in which they overcame those challenges. Individuals and groups share what they’ve learned through the assembly process. |  |

**Activities** (Class 2)

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| **Time** | **Activity Type** | **Activity Description** | **Notes** |
| 5 min | Whole Class | Instructor outlines the day’s objectives and expectations. |  |
| 5 min | Small Group | Learners rotate an external permanent magnet near the end of their motor by hand to operate it and record their observations. | Learners should feel the alternating forces between the magnets as the motor moves. |
| 5 min | Small Group | Learners operate their motor using a magnetic pole reverser positioned near the end of their motor and record their observations. | Each group of learners should receive one pre-assembled magnetic pole reverser. |
| 5 min | Small Group | Learners operate their motor by connecting a battery to the solenoid of their motor before switching the leads connected to the battery terminals and recording their observations. |  |

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| **Time** | **Activity Type** | **Activity Description** | **Notes** |
| 5 min | Small Group | Learners fabricate and test a simple reed switch as a group. |  |
| 5 min | Small Group | Learners connect the reed switch to their motor circuit, use it to control the electrical current in the solenoid, and then record their observations. |  |
| 5 min | Small Group | Learners operate their motor using a rotating motor controller and record their observations. | Each group of learners should receive one pre-assembled magnetic rotating motor controller. Learners should replace their reed switch in the motor circuit with the reed switch on the motor controller. |
| 15 | Whole Class | Groups share their observations and learners discuss the relationships they found between magnetism and electricity and how they can be used to create motion. |  |

**Optional Extensions**

* Learners create their own inventions using the linear motor. Examples include drum machines, physical animations, and other mechanisms.
* Learners experiment with how the number of wraps on the solenoid and the electrical current passing through them affect the strength of the electromagnet by varying each and recording their observations.
* Learners connect their linear motors to an audio frequency oscilloscope and explore how it can be used to control the movement of the motor. ([SoundScope Audio Frequency Oscilloscope](https://maketolearn.org/soundscope))
* Learners connect their linear motors to a microcontroller and explore how the movement of the motor can be controlled using computer code.