# *Electrodynamic Propulsion*

## DESCRIPTION

This activity challenges your students to solve a real-world problem that is part of the space program using creativity, cleverness, and scientific knowledge, while learning about electricity, magnetism, forces, and energy transfer.

**NASA SUMMER OF INNOVATION**

**UNIT**
*Engineering: Challenges*

**GRADE LEVELS**
*7 – 9*

**CONNECTION TO CURRICULUM**
*Science, Math, Technology, and Engineering*

**TEACHER PREPARATION TIME**
4 – 8 hours

**LESSON TIME NEEDED**
*Twelve 45-minute sessions* *Level: Advanced*

## OBJECTIVES

Students will

- Investigate how different configurations of current-carrying wires behave in the presence of a specific, hand-held magnet
- Observe a design before testing and pick out the "key features"
- Observe a model during and after testing and document precisely what happens to the model
- Apply the engineering design process
- Record observations and organize data so that they can be exchanged with others

**NATIONAL STANDARDS**

**National Science Education Standards (NSTA)**
*Science as Inquiry*
- Understanding of scientific concepts
- Understanding of the nature of science
- Skills necessary to become independent inquirers about the natural world
- Dispositions to use the skills, abilities, and attitudes associated with science

*Physical Science Standards*
- Position and motion of objects

**Common Core State Standards for Mathematics (NCTM)**
*Expressions and Equations*
- Apply and extend previous understandings of arithmetic to algebraic expressions
- Reason and solve one-variable equations and inequalities
- Represent and analyze quantitative relationships between dependent and independent variables
- Solve real-life and mathematical problems using numerical and algebraic expressions and equations
- Understand the connections between proportional relationships, lines, and linear equations

**ISTE NETS and Performance Indicators for Students**
*Creativity and Innovation*
Students:
- Apply existing knowledge to generate new ideas, products, or processes
- Create original works as a means of personal or group expression
- Use models and simulations to explore complex systems and issues
- Identify trends and forecast possibilities

*Critical Thinking, Problem Solving, and Decision Making*
Students:
- Identify and define authentic problems and significant questions for investigation
- Plan and manage activities to develop a solution or complete a project
- Collect and analyze data to identify solutions and/or make informed decisions
- Use multiple processes and diverse perspectives to explore alternative solutions

**MANAGEMENT**

To prepare yourself and your classroom for this Engineering Design Challenge, you should

- Use the Background Information section in this guide, and the Engineering Design Challenge Web site at http://edc.nasa.gov to electromagnetic structures used by NASA and the science and engineering concepts you will be introducing.
- Build the test assemblies and train models.
- Notify parents using the flier included in the back of the guide.

**CONTENT RESEARCH**

**Propulsion Systems:** NASA engineers are busy developing systems that will help move satellites in orbit—such as the International Space Station or various communications or research satellites—without using the rocket propellants that currently do this job. It costs a lot to launch the necessary rocket fuel into space, so NASA seeks to develop a lightweight, inexpensive, and convenient alternative way to move spacecraft. Not only would such an alternative save money but also it would reserve space and weight for equipment and supplies.

**Forces:** Generally, a force is any push or pull on an object. Many of the forces we think about require physical contact to work. Turning a doorknob requires that we touch the knob to apply a twisting pressure. Jumping into the air requires that our feet touch and then push off the ground. Walking a curious dog requires that we pull on a leash that is attached to the dog's collar. Other forces do not require contact between the objects that are being pushed or pulled. For example, gravity is a force of attraction that affects objects, even when they are not touching. After jumping into the air, we are not touching the Earth, yet this force works to pull us back to it. (By the way, ever so slightly and imperceptibly we also pull the Earth towards us).

**Magnetism:** Another force that can work on two objects, even when they are not in physical contact with one another, is magnetism. For example, the magnetism of a small bar magnet causes a paper clip to leap towards it, before the magnet actually physically contacts the clip. In addition, magnets can push and pull on each other. This is something you can observe readily with two bar magnets.

**Magnetic Effect on Electric Wires:** A magnet can make a wire move, if that wire is conducting electricity. The magnet exerts a force on the wire. The term "magnetic effect of current" is defined as, "a current flowing in a wire produces a magnetic field around it." The magnetic effect of current was discovered by Oersted in 1820. Oersted found that a wire carrying a current was able to deflect a magnetic needle. Now, a magnetic needle can only be deflected by a magnetic field. Thus, it was concluded that a current flowing in a wire always gives rise to a magnetic field around it. The magnetic effect of current is called electromagnetism, which means that electricity produces magnetism.

**Electrodynamic Tethering Systems:** The idea of using the magnetic effect on electric effects of the geometry of the wire in relation to magnetic field. NASA engineers will put this effect to work in space. From an orbiting satellite, they will extend a long, electrically conducting wire, a so-called electrodynamic tether. The Earth's magnetism will push the wire. If the force is great enough, not only the wire, but also the spacecraft attached to it, will move. Interestingly, in space, it does not take much force to move a satellite. NASA is hoping to generate a force roughly equivalent to the force required to lift about half a cup of milk. This modest force, applied intermittently over time, will be sufficient to keep the International

**MATERIALS**

- Train track with prepared and modified model train
  - 1 electrically wired HO gauge passenger car with metal wheels.
  - 1 thin, flat-bladed screwdriver
  - 2 double-headed alligator clip leads

- Magnetic Push Test Stand
  - Stack of books about 10 to 12 inches high
  - Stiff cardboard platform, the same size as a text book cover
  - 1 double-cell battery holder for D cells
  - 2 D cell batteries
  - 3 double-headed alligator clip leads
  - 1 light bulb holder for a #13 bulb
  - 1 #13 bulb
  - Ruler (centimeter and millimeter markings)
  - Velcro (about 1 inch of each side)
  - Cellophane tape

- Wire Arrangement Card for Magnetic Push Test Stand
  - Manila folder strip
  - Scissors
  - Roll of wire
  - Tape
  - Magnetic Push Test Results Sheet
  - Film canisters, bottles, markers, and other optional shapes to use as cores, around which you will wrap the wire
  - Sand paper (1 by 2 inches)

Platform Base to Accept Students' Mounted Wire Assemblies

- Train car, prepared as above
- Sharp scissors
- Sturdy cardboard, about half the size of the train top (can be corrugated
- Cardboard or a heavy-duty report cover)
- About 1 foot of adhesive-backed Velcro—the soft, fuzzy side (loops side)
- Cellophane or more adhesive tape

Space Station in orbit indefinitely. This electrodynamic push could replace rocket propulsion for orbital maneuvers. Roughly one-billion dollars worth of fuel launches—100,000 pounds of fuel—would be saved over 10 years.

## LESSON ACTIVITIES

- Session 1: Introduction to engineering; introduction to student engineering project, in which students meet a challenge. Introduction of NASA's propulsion challenge and how NASA engineers hope to solve it; and introduction of classroom challenge based on same idea. Introduction of magnet wire, a key material used throughout the challenge project. Explain data recording sheets, journals, and culminating activity.
- Sessions 2 and 3: Student engineers explore different wire arrangements responses to the cow magnet. Students collect, share, and analyze data from this research, identifying promising features to include in their designs. Students also begin to talk about their emerging understanding of the magnetic effect on the wire. Review safety issues found in the guide introduce the materials and design, build, test, record, and share solutions.
- Sessions 4 through 8: Students experience the design-test-revise-redesign engineering cycle. They may integrate the Magnetic Push Tests into their design work. As they gain more experience observing the effect of a magnet on a current-carrying wire, they continue to identify some key features to include in their wire arrangements, and consider how mounting the arrangement might affect its performance.
- Sessions 9 through 12: Construct a storyboard or poster of final design testing results, sketches, steps throughout development, and journals. Students reflect on their ideas about why specific design features help generate a stronger force and move the train. They review their engineering process and develop storyboards to share these insights with others. Finally, students compare their work with the work of engineers at NASA.

**Resource Web site:**
Download the NASA Educator Guide: http://edc.nasa.gov/docs/PROPULSION.pdf

## RELATED RESOURCES

Design An Ion Engine: http://dawn.jpl.nasa.gov/mission/ion_engine_interactive/index.html

Engineering Design Challenges Web site: http://edc.nasa.gov

NASA Career Corner for Grades 5 – 8: http://www.nasa.gov/audience/forstudents/5-8/career/index.html

Discover Engineering Online: www.discoverengineering.org

NASA Education Home Pag: http://education.nasa.gov

## DISCUSSION QUESTIONS

- How can we push on an object so it moves the way we want it to? Or how do we apply force to an object so it moves the way we want it to? *A force is a push or a pull; they must apply the force in the direction they want the train to go.*
- How do we apply a propulsive force to an object so it moves the way we want it to? *To propel the train, students will specifically use an electromagnetic push, the force of magnetism against a wire that has electricity flowing through it. Students will equip the train with an electric wire, which will respond to magnetism by moving.*
- How can we get enough propulsive force to actually move the satellite? *Answers will vary.*
- How can we direct the force so that we can make the satellite go where we want it to go? *Orientation of the magnet to the wire, geometry of the wire, direction of the electrical flow, and the way the wire is mounted to the train.*
- How can we control the system so it does not cause other major problems for the satellite? *Answers will vary.*
- How can we optimize the system? *The geometry of the wire and the way the wire is mounted to the train.*

- What specific design features will work best? *Answers will vary and will be determined by experimentation.*
- How can we design this electrodynamic system to get a force strong enough to move the train? *Answers will vary and will be determined by experimentation.*
- What happens when electricity flows through the wire? *The train moves.*
- What happens when electricity does not flow through it? *The train does not move.*
- How would students describe the amount of movement, its direction, and its path? Is the motion predictable? *Answers will vary and will be determined by experimentation.*

## ASSESSMENT ACTIVITIES

Use a rubric to evaluate student's work on the storyboards, journals, and presentations of their test results, designs, and solutions to the challenge. Criteria for evaluation are included in the educator guide.

## ENRICHMENT

### Optional Extensions for Use After Session Three:

Conduct additional Magnetic Push Tests on the predetermined wire arrangements.

Conduct controlled experiments with Magnetic Push Tests and student-designed wire arrangements.

Conduct Magnetic Push Tests on student-designed wire arrangements before mounting them on the train.

**www.nasa.gov**