Magnet Circus

Design Challenge Learning

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Students explore the properties of magnets by designing a device that mimics the movements of circus performers using only magnetism, and then design a machine that will stay in motion for the greatest period of time. As they iterate through the design challenge, students gain firsthand experience in the design process.

Grades 3-8

Estimated time: 60 minutes

Student Outcomes:

1. Students will be able to create a device that demonstrates the properties of magnetism, magnetic fields, and polarity.
2. Students will be able to utilize the three step design process to meet an engineering challenge.

Next Generation Science Standards

Grade 3-5: *Engineering Design* 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
Grade 3: *Physical Science* 3-PS2-3, 3-PS2-4
Grade 4: *Physical Science* 4-PS3-2, 4-PS3-4
Grade 5: *Physical Science* 5-PS1-3
Grade 6-8: *Engineering Design* MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4; *Physical Science* MS-PS3-5

Common Core Language Arts-Speaking and Listening

Grade 3: SL.3.1b-d, SL.3.3, SL.3.4a
Grade 4: SL.4.1b-d, SL.4.4a
Grade 5: SL.5.1b-d, SL.5.4
Grade 6: SL.6.1b-d
Grade 7: SL.7.1b-d
Grade 8: SL.8.1b-d

California Science Content

Grade 3: *Physical Science* 1.c-d; *Investigation and Experimentation* 5.a-b, d
Grade 4: *Physical Science* 1.f-g; *Investigation and Experimentation* 6.a, 6.c-d
Grade 5: *Investigation and Experimentation* 6.a-c, 6.h
Grade 6: *Investigation and Experimentation* 7.a-b, 7.d-e
Grade 7: *Investigation and Experimentation* 7.a, 7.c-e
Grade 8: *Physical Science* 2.a-f; *Investigation and Experimentation* 9.a-b

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Vocabulary:

Familiarity with these terms and concepts will enhance students' experience in the activity.

- Electron: An elementary particle having a negative charge, found outside the nucleus of an atom.
- Energy: The ability to do work. Appears in many forms, all of which are either kinetic or potential.
- Force: A push or a pull. An influence on a body or system, causing or tending to cause a change in movement or shape.
- Kinetic Energy (KE): Energy of motion. Includes heat, sound, and light (motion of molecules).
- Machine: A tool using or applying mechanical energy and having several parts, each with a definite function and together performing a particular task.
- Magnet: An object composed of magnetic material that is able to produce its own magnetic field.
- Magnetic Field: An invisible field produced by magnetic objects or electrical current. Magnetic fields can exert force on magnetic items or moving electrons.
- Magnetic Poles: The two ends of a magnet where the magnetic field is concentrated. All magnets have two poles with equal magnetic strength.
- Perpetual Motion: motion that continues indefinitely without any external source of energy. This is impossible to ever achieve because of friction and other sources of energy loss.
- Potential Energy (PE): Energy of position; energy that is stored and held in readiness. Includes chemical energy, such as fossil fuels, electrical batteries, and food we eat.

Resources:

- Explain That Stuff: A great introduction to the science and history of magnetism. http://www.explainthatstuff.com/magnetism.html

- Magnetism Resources: This website offers many additional resources on magnetism, electromagnetism, and planetary magnetic fields. Students and teachers have access to pictures, articles, videos, games, and puzzles all related to properties of magnetism. http://www.neok12.com/Magnetism.htm

- NASA: The Nasa website has many resources for both teachers and students. Students and teachers will not only find abundant information on our galaxy and space research, but also activities, videos, and much more to help connect magnetism to earth science. www.nasa.gov

- The Museum of Unworkable Devices: A website that houses information on perpetual motion machines. It contains a history of perpetual motion machines, science facts about why perpetual motion machines don't work, animations of different attempts to achieve perpetual motion, and other resources on these impossible machines. www.lhup.edu/~dsimanek/museum/unwork.htm

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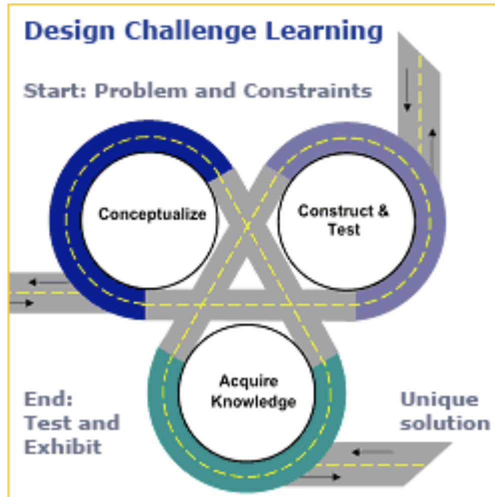
Design Challenge Process:

The Design Challenge Process is designed so students reinforce their science, mathematics, social studies, and language arts content knowledge, through an open-ended process that results in an original, team-driven solution. Students are expected to take responsibility for assessing their own progress and incorporate peer feedback as they conceptualize and redesign their projects.



The process consists of three interconnected steps:

Conceptualize
- Identify problem, materials, and constraints
- Brainstorm ideas and possible solutions

Construct and Test
- Select a solution
- Design and construct
- Prototype
- Redesign or modify
- Retest

Acquire Knowledge
- Research
- Share solutions
- Reflect and discuss

Through the try, fail, learn approach, students develop skills and habits of mind of Silicon Valley innovators: creativity, problem solving, design, collaboration, leadership, risk-taking, perseverance, and learning from failure.

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Materials:

Materials can be limiting or inspirational to students! Have a wide variety of materials to promote a diversity of solutions. "Recycled items" are really useful: old mouse pads, wood scraps, boxes, cardboard tubes, strawberry baskets, etc.

One Set Per Team of 4 Students:

- Assorted Tinker Toys
- Assorted Magnets (Ring, bar, cow, etc.) – minimum 3

Class Supplies to Share:
Cirque du Magnets

- Additional Tinker Toys
- String
- Pipe Cleaners
- Washers
- Paper Clips
- Magnetic Counting Chips
- Old Compact Discs
- Non-magnetic Metal Objects (Aluminum foil, pennies, etc.)
- Low Friction Materials (glossy cardstock, plastic, etc.)
- Masking Tape
- Scissors
- Magnaprobes or Compasses (optional)

Class Supplies to Share:
Perpetual Motion Machine

- All the Supplies from Cirque du Magnets List
- Pictures of Perpetual Motion Machines
- Craft Sticks
- Wooden Skewers
- Toothpicks
- Twist Ties
- Scraps of Wood
- Rubber Bands
- Hot Glue Guns
- Stiff Recycled Paper (barcode cards, brochures, etc.)
- Nails
- Assorted Tubes

Directed Instruction:

- Magnaprobes or Compasses
- Red and Blue Dot Stickers
- Magnets
- Bar Magnet in a Plastic Sleeve, Transparency Sheet or Sheet of Glass
- Iron Filings
- Overhead Projector
- Maglev Train Model (optional)
- Square of Sand Paper
- Wooden Block

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<u>Lesson Plan:</u>

Introduction *(5 minutes)*

1. Ask students about the types of amazing feats or entertainment you might find at a circus or carnival. These might include acrobatics, trapeze artists, balancing on a tightrope, defying gravity, carousels, or Ferris Wheels.
2. Tell students that just like circus feats, magnets can do amazing things. Ask students what they know about magnets. They may share observations about magnets attract all types of metal. You can ask them if magnets attract all types of metal to get them thinking about materials and their properties and spur exploration during the first challenge.
3. Explain that often innovators will try to use the unique properties of a material in a new invention and often take inspiration from life. They will be working on designing circus-inspired entertainment using the properties of magnets.

Cirque du Magnet Challenge *(15 minutes)*

1. <u>Introduce the Challenge</u>: Design a circus act using the properties of magnets.
2. <u>Introduce the Constraints</u>:
   - Each circus act must make use of a magnet to start the motion.
   - Each circus act must use a minimum of two magnets but no more than 3-5. (Adjust the number based on the number of magnets you have available to students.)
   - Each circus act must make use of at least one magnetic material.
   - Each circus act must be entertaining!
   - Identify the inspiration for your act. (optional)
   - You may use only the materials provided.
   - All team members must be involved.
3. <u>Build:</u> Give students about 10 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker.
4. <u>Demonstration</u>: Have students demonstrate their act for the class. If students have not completed their device ask them how the act would have worked. This should last no more than 5 minutes.
5. <u>Reflection</u>: Each group of students will explain their design strategy and how they used the properties of magnets in their act. Instructor should ask leading questions to get at the science behind the designs.

Directed Instruction (Magnetism, Forces, and Mass) *(10 minutes)*

1. Ask questions to encourage teaching points:
   - How did you position the magnets to start the movement of your act?
   - How many different ways did your magnets interact with each other?
   - How did you use your magnetic material in your act? Which materials were magnetic? Which materials were not magnetic?
   - Were you able to repel magnetic metal using magnets?
   - What causes the motion of your magnet or magnetic material to slow down and stop?
2. Magnets have two poles (north and south). Like poles repel each other and unlike poles attract each other.
   - <u>Demonstration:</u> Demonstrate how to use a magnaprobe or a compass to detect the magnetic force of a magnet and to see how and where the poles flip from north to south. Have students use the magnaprobes or compasses to find the north pole of a magnet (blue) and the south pole

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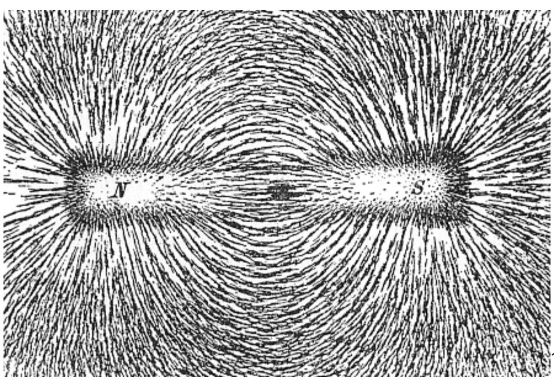
of their magnet (red) and label these with red and blue dot stickers which they mark with an N for north or S for south. Doing this for all their magnets will help them a great deal in the next challenge.

- Questions:
  - How can you position the magnets so that they repel each other?
  - How can you position the magnets so that they attract each other?

3. Magnets exert a force around them called a magnetic field.

- Demonstration: Demonstrate a magnetic field using a document camera or on an overhead projector using a bar magnet with a sheet of glass, transparency sheet, or sheet protector on top of it. Pour iron filings over the magnet and watch the filings move into a pattern of arcs from one end of the magnet to the other, lining up in the direction of the magnetic force. You may want to overlay a transparency showing the line drawing of the field around the magnet as seen below.
- Questions:
  - What pattern do the filings make around the magnet?
  - What causes this pattern?
  - Where is the force the strongest?
  - Where is the force the weakest?



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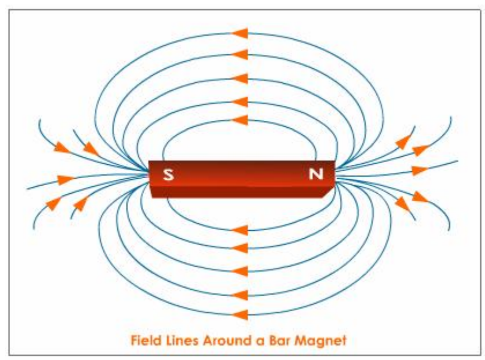

[2]

4. Friction is the resistive force that happens when two surfaces rub against each other. If no friction or other force acts on a moving object, it will continue to move. (An object in motion will remain in motion until another force acts upon it.) The greater the mass of an object the more force is needed to achieve the same rate of motion.

- Demonstration: Tape a piece of sand paper to the table with the rough side up. Demonstrate that when you attempt to push a wooden block across the smooth table top the block easily slides, but when you attempt to push the wooden block across the sand paper it is more difficult to get the block to slide. It takes more force to slide the block across the sand paper than it does across the smooth surface of the table.
- Questions:
  - What will friction cause to happen to a body in motion?
  - Why will an object slow down if friction is present?
  - What does the surface texture of an object tell us about the extent that friction will play on that moving object?

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[1] Newton Henry Black, Harvey N. Davis (1913) *Practical Physics,* The MacMillan Co., USA, p. 242, fig. 200
[2] Field Lines Around a Bar Magnet. Digital image. *Mapping of Magnetic Lines of Force.* TutorVista, 2014. Web. 2 April 2015. http://www.tutorvista.com/content/science/science-ii/magnetic-efffects-electric-current/mapping-magnetic-lines.php#.

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Perpetual Motion Machine Design Challenge *(35 minutes)*

1. Explain that now that students have played with the properties of magnets, they will now think about another whimsical application of magnetism to design a device using magnets to keep something moving as long as possible.
2. Show students some drawings of perpetual motion machines such as the rotating Earth or Escher's closed cycle of water flowing infinitely. Discuss why the latter machine is impossible and notice that many of these machines move in a circle or cycle. Tell them that they are going to think about how they can keep something in perpetual motion (or in motion for as long as possible) using magnets.
3. Introduce the Challenge: Design and build a "perpetual motion" sculpture using the provided materials to remain in motion for the greatest period of time.
4. Introduce the Constraints:
    - Each sculpture must use a minimum of two magnets but no more than 3-5.
    - Each sculpture must make use of at least one magnetic material.
    - Each sculpture must make use of a magnet to start the motion.
    - Human interaction with the sculpture is limited to triggering the start of motion by positioning the magnet, which must then stay in that location.
    - Sculptures should be in motion for at least one minute.
5. Build: Give students about 20 minutes to build. Instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker.
6. Discussion/Demonstration: Have each team demonstrate their sculpture to the class, describe how they used magnetic poles to begin and continue the motion of their device, how they reduced friction and mass, and what they found challenging. Explain that engineers have never been able to build a machine that moves forever. Even the Earth's rotation is slowing very slowly.