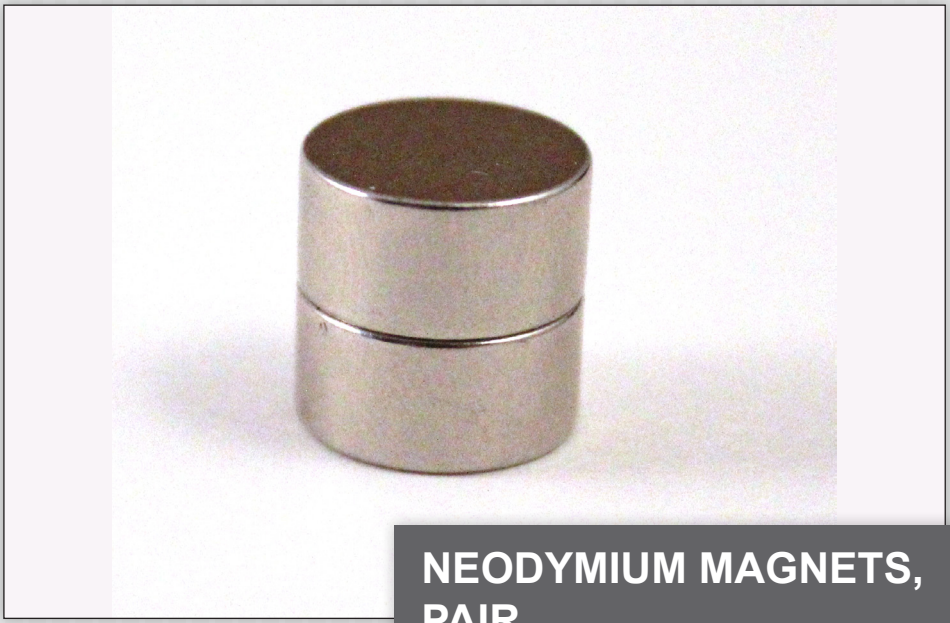
TEACHERS GUIDE



NEODYMIUM MAGNETS, PAIR

ITEM # 3114-01

NON-CONTACT FORCES - ELECTROMAGNETIC INDUCTION

Neodymium iron boron (NIB) magnets are extremely strong and have a magnetic pull-force that is 20,000 times greater than the Earth's magnetic field! There are many exciting experiments that can be done with these magnets, and the electric fields that they induce, including magnetic "braking", levitation, separating iron from food, and detecting magnetic properties of food and money! Magnets appear to be magic because they exert forces on objects without touching them.

Materials

- total cereal
- mortar and pestle
- copper pipe
- paperclips
- string
- dollar bill
- clothing pin
- straw
- grapes
- styrofoam cup
- ¼ “ and 1/16 ” aluminum
- ½ “ thick piece of wood
- ½ “ slab of copper that is several inches wide
- liquid nitrogen (or rubbing alcohol and dry ice)
- regular magnets of similar volume as the neodymium magnets
- stopwatches

Goals & Objectives

See page 7 for Next Generation Science Standards

History

Discovered in 1982 by General Motors and Sumitomo Special Metals. This is an alloy of the rare earth element neodymium ad boron and iron. The great attractive force in these magnets requires special safety and care when using them. They are very brittle and shards can chip off or pinching can happen.

How it works

Lenz's Law: Electric current generated by a moving magnet will always oppose the original motion of the magnet that created the current.

If the material is diamagnetic, the object will be very slightly repelled because all electrons in orbitals are paired in the substance. If the material is paramagnetic, the object will be very slightly attracted because there is at least one unpaired electron in an orbital.

Copper is more conductive when it is cooler. Metals contract when cooled and the atoms get even closer and the electron "sea" is even more delocalized.

ASSESSMENT

1. • Participation, Discussion and Vocabulary

2. ***Vocabulary/Glossary***
   - diamagnetism
   - electromagnetic forces
   - electromagnetic induction
   - Lenz Law
   - paramagnetism

ACTIVITIES

1. *Hand and paper clips:*
Place a regular magnet on top of your hand to see how many paper clips you can pick up under your palm.

2. *Total Cereal:*
Use a mortar and pestle to finely crush Total Cereal. Place a NIB magnet in a plastic sandwich bag and swirl in the Total cereal dust. Iron that is added to the cereal will be attached to the outside of the baggie.

3. Dollar bills have magnetic strips in them. An NIB magnet will detect it.

4. Roll, on edge, an NIB magnet on a glass plate and it will align with the earth's magnetic field. Hang a strip of NIB magnets from a string and it will align with the magnetic tilt of the earths field as well

5. Compare shielding effect of regular magnets to NIB magnets – shielding is when a neutral material is placed in between at least two electrical or magnetic fields. Your hand shielded the attraction of the NIB magnet for the paper clips in Activity 1.
   a. Ask students to design an experiment to test the shielding effect of different materials (cardboard, glass, plastic, etc.)

6. Diamagnetic and Paramagnetic – Stick two grapes on the end of a straw and balance the straw on a pin stuck through an upside down Styrofoam cup.
Move a neodymium magnet near one of the grapes, and it will move away from the magnet. Then, turn the magnet over. Although you expect the grapes to be attracted, it is repelled again. This happens because the water in the grape is diamagnetic and is repelled by both poles of a magnet.
   a. Hang a small amount of a substance from a string and bring the NIB magnet close. If the object is attracted, the substance is paramagnetic and if the object is repelled, it is diamagnetic

7. *Electromagnetic Induction Race:*
Use ¼ " and 1/16 " aluminum slabs wide and long enough to use as a ramp, ½ " thick piece of wood also long and wide enough to use as a ramp. Assign a few students as releasers and a few as timers.
Hold the ramps at 45 degree angles and release NIB magnets on edge. The effects of the Lenz Law electromagnetic braking will be obvious.

***Note**
It is always best to DO an experiment ahead of time to be able to best present it to the class.

ACTIVITIES

Students can feel the opposing electric force generated by just laying the aluminum ramp flat and holding the NIB magnet in their hand and running their hand across the aluminum.
Compare the other materials doing this. Repeat with regular magnets.

What questions can students generate about their observations to research? For instance, would copper be the same opposing force?

8 *More electromagnetic induction:*
Drop an NIB magnet into a length of copper pipe. It moves slowly because of the opposing electric force induced from the magnet moving through a conductive material.

a What force is it opposing? (gravity)

If you chose a piece of copper pipe that has a slip fit – it will drop VERY slowly. There is a green magnetic field viewing film that can be cut into strips and taped to the coper pipe to view the fall of the magnet.

b Ask students to predict if a large magnet will fall faster or slower? What about a pipe made of a different material? Thicker-walled pipe?

9 *Super-electromagnetic induction:*
Cool a one inch slab of copper with about a 10” diameter in a shallow tub of liquid nitrogen. (It is also possible to make a cryo-liquid with dry ice and isopropyl alcohol). **Use appropriate safety equipment (cryo-gloves and goggles) when using liquid nitrogen to prevent frostbite burns and practice this before demonstrating it.**
Copper becomes even more conductive when cooler. Drop, on edge, the NIB magnet and it will bounce up and then slowly settle back down due to the opposing electrical force induced.

There are several Youtube videos demonstrating the proper technique and the observations to expect. https://www.youtube.com/watch?v=8uYqxhlObHg

Discussion

Additional Discussion and Real Life Applications

1. How do amusement parks use Lenz's Law? Why use NIB magnets in audio speakers instead of regular magnets?

2. Ask students to investigate other demonstrations that they can share with the class and explain the observation using scientific concepts and data.

3. Ask students to plan and conduct an experiment to test how many paper clips a NIB vs regular magnet can pickup.

4. ***Advanced High School:*** Ask your students to design a way to demonstrate and test how thrill rides use electromagnetic induction (spherical magnet, copper coil hoop, and aluminum track comes to mind)

Next Generation Science Standards

Students who demonstrate understanding can:

3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

3-PS2-4. Define a simple design problem that can be solved by applying scientific ideas about magnets.

MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science

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.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