Invisible Investigations

Overview: Using indirect observational methods, you can distinguish between charged and uncharged objects.

Grades: 4-8 (See links to national science and math standards at the end.)

Time: 45 minutes to an hour

Background: Everything is made up of stuff we call matter and matter is made up of tiny particles that we cannot directly see. Particle detectors have a variety of mechanisms to 'detect' these particles. Accelerators are machines that accelerate or speed up particles. Particle physicists can use accelerators to smash particles together in the detector and look for what is left over. Some of these mechanisms use a magnetic field that causes charged particles to deflect, or change direction. How much it changes direction depends on the speed, mass, and charge of the particle. The change of direction depends on the type of electric charge the particle has (positive and negative deflect in opposite directions). Non-charged or neutral particles show no change of direction.

This lesson uses magnetic marbles to represent charged particles and iron filings to represent a method of detecting "charged" particles (the marbles are not really electrically charged, but represent a charged particle). You will notice that a magnetic marble rolling near iron filings will cause them to stand up when the marble (particle) is near. The filings lie back down after the marble (or particle) passes. They stand up because iron filings have groups of atoms that align themselves parallel to magnetic fields.

Once the marble passes into the detector, you cannot directly observe or see what the marbles are doing, but you can watch the behavior of the filings. Particle physicists cannot see the particles they collide, even before the collision, but they can observe how they affected, such as how they move in a magnetic field. The magnetic marbles and iron filings demonstrate how we can make something that we can't directly see observable. Non-magnetic marbles will not move the iron filings just as non-charged particles are not affected by the magnetic fields within a particle detector.

The iron filings can be used to examine the magnetic fields of magnets. Just place the magnet under a sheet of paper or piece of cardboard and sprinkle filings on top. The filings will line up parallel to the magnetic field lines of the magnet. Tapping the cardboard lightly helps to align the filings.

Objective: To simulate the movement of charged particles in a magnetic particle detector.

Materials: Each student needs:

- Magnetic marbles
- Nonmagnetic marbles
- Iron filings (A cheap source of iron filings are soapless steel wool scrubbing pads, wear gloves when cutting these up.)

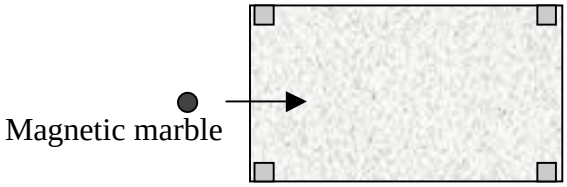
• Two stiff surfaces (nonmetallic) about the size of a piece of paper (8.5x11) or larger that can support iron filings and not impede marbles rolling beneath (e.g. cardboard, foam display board, masonite/white board).
• 6 stacks of pennies (14 pennies high) or any objects (2 cm high) to support the stiff surface high enough to allow marbles to roll beneath unimpeded

These items are available and inexpensive at local stores, but if you have difficulty finding the marbles and iron filings, most science education suppliers have these, such as:
Frey Scientific (1-800-225-3739) or www.freyscientific.com
Sargent-Welch (1-800-676-2540) or www.sargentwelch.com
Nasco Science (1-800-558-9595) or www.eNASCO.com

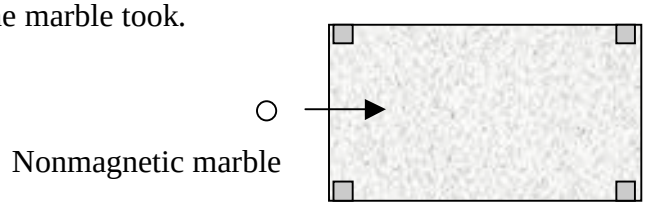
Procedure:

1. Set up the stiff surface to resemble a table (high enough for marbles to roll beneath) with the supports on the outside four corners. Sprinkle the iron filings evenly over the surface.

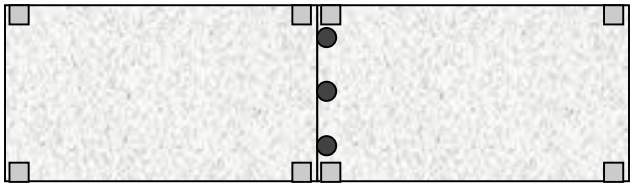
2. Roll a magnetic marble beneath the "table" and observe the tabletop. Record your observations on the worksheet (A) including a sketch of the path that the marble took.



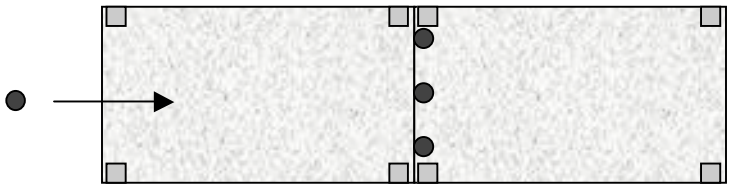
3. Pick up the "table" top and shake it to evenly distribute the iron filings. Roll a nonmagnetic marble beneath the "table" and observe. Record your observations on the worksheet (B) including a sketch of the path that the marble took.



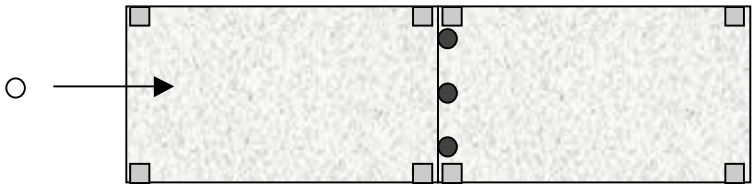
4. Make another "table" and put it end-to-end with the other "table" (see below). Place three magnetic marbles beneath the edge of the second table. Pick up the original "table" top and shake it to evenly distribute the iron filings. Evenly sprinkle iron filings over the second "table".



5. Roll a magnetic marble beneath the two tables and observe. Record your observations on the worksheet (C) including a sketch of the path that the marble took.



6. Pick up the "table" tops to reposition the marbles if needed and shake them to evenly distribute the iron filings. Roll a nonmagnetic marble beneath the two tables and observe. Record your observations on the worksheet (D) including a sketch of the path that the marble took.



7. Pick up the "table" tops and shake them to evenly distribute the iron filings. Have one student replace one or two of the magnetic marbles under the edge of the second "table" with nonmagnetic marbles. Have another student roll a magnetic marble under the "tables" and observe. Record your observations on the worksheet (E) including a sketch of the path that the marble took.

Results and Discussion:

A. Iron filings stand up and lie down as the magnetic marble passes beneath them.

B. Nothing happens to the iron filings since the marble is nonmagnetic.

C. The iron filings stand up above the stationary marbles and above the moving magnetic marble. If the moving marble passes close enough the other magnetic marbles under the second "table", it will change direction.

D. The nonmagnetic marble isn't detected by the iron filings or affected by the magnetic marbles unless it actually hits one.

E. The iron filings stand up above the stationary marbles and above the moving magnetic marble. If the moving marble passes close enough to other magnetic marbles under the second "table", it will change direction. It will not change direction if it passes a nonmagnetic marble (unless it hits it).

Further Questions:
Electrons, neutrons, and protons are too small to directly see. Quarks are even smaller. Electrons, protons and quarks have electrical charges. Electrons are negatively charged, protons are positively charged and quarks can be positive or negative depending on what kind they are. How do you think scientists can use the fact that particles have charges to detect them? Particle physicists use magnetic fields to see how different particles react to them. The direction it moves, and how big the deflection from its original path is, depends on the kind of particle, whether it is positive or negative, how big the charge is, and how fast it is going.

Follow up activities:

a. Lesson plans *What shape is it?* and *Magnet Mania* also explore how to find out about something you can't see.
b. To learn more about particle physics and how detectors work, check out the www.fnal.gov site.

NATIONAL STANDARDS

This lesson plan addresses the following national standards in science and math:

Science

Standard A – Science as Inquiry
Students should develop abilities necessary to do scientific inquiry and an understanding about scientific inquiry.

Standard B-Physical Science
Students should develop an understanding of the properties of objects and materials including electricity and magnetism as well as motions and forces of objects.

Standard E – Science and Technology
Students should develop abilities of technological design and an understanding about science and technology.

Standard G-History and Nature of Science
Students should develop understanding of the nature of science.

Math

Analyze change in various contexts
- Describe qualitative change, such as a student's growing taller

Data Analysis and Probability Standard
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
- Pose questions and gather data about themselves and their surroundings;
- Sort and classify objects according to their attributes and organize data about the objects;
- Design investigations to address a question and consider how data-collection methods affect the nature of the data set;
- Collect data using observations, surveys, and experiments;