Nanotechnology
Floating Magnet Set
User Guide

PITSCO EDUCATION

Introduction

Welcome to the very small world of nanotechnology. This kit is intended to provide a tool to visualize the process of self-assembly at the molecular level.

While many texts provide information about how materials are built from component parts at the molecular level, this concept remains abstract for most people. By manipulating building blocks that have certain magnetic properties, students see how the construction of a specific molecule or material might occur at the molecular level.

This guide is to help use this kit and to explore:

- Magnetic forces
- Equilibrium
- Self-assembly at the nano scale
- Crystal lattice structures

Materials Included

- 1 – 10-inch clear container with lid
- 18 encapsulated neodymium magnets
- 30 ceramic magnets
- 2 sheets of foam building blocks
- Compass

Required (not included)

- Permanent marker such as a Sharpie
- 1 or more clear rectangular containers (if doing the Crystal Lattice Structures activity)

Warning!

Magnets may be harmful if swallowed. If anyone swallows a magnet, contact a physician immediately.

Setup

Note: You may choose to have students do the setup or you can do it.

Locate the two sheets of foam building blocks. Using a permanent marker, write "N" (for north) on each of the building block shapes. Mark only one side of each building block. Remove all the building blocks from one of the foam sheets.

Locate the 18 encapsulated neodymium magnets (Nd magnets – Nd is the chemical symbol for the element neodymium). Most likely, they will have oriented themselves into a line. If not, carefully maneuver them into this configuration (Figure 1).

Locate the compass and move it away from any source of magnetism (such as the magnets in the kit). Make sure the compass needle points north.

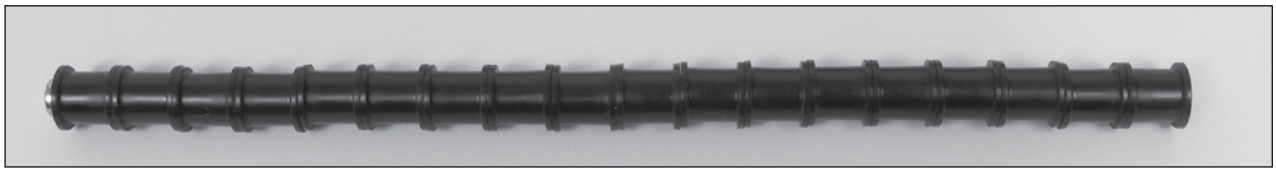


Figure 1

Move the compass near the line of Nd magnets and determine which end of the line is north – the north end of the line will attract the south pole of the magnet. Remove one of the magnets from the line, noting which end of the magnet is the north end.

Insert the magnet into the hole in the center of one building block so that the north end of the magnet is at the side of the block labeled "N."

Remove the next magnet from the line. Insert it into another building block, again orienting the north end of the magnet with the side of the block labeled "N." Repeat this process until there are six each of circular, triangular, and square building blocks with magnets.

The remaining sheet of blocks can be used as replacements or to provide more blocks of a specific shape, if needed.

Basic Configuration

The round plastic container in this kit provides excellent viewing and vertical walls for the activities. Square, rectangular, or other container shapes can be used as well, but each will provide a different environment to cause the building blocks to make different patterns. Be sure any container used is not magnetically attractive.

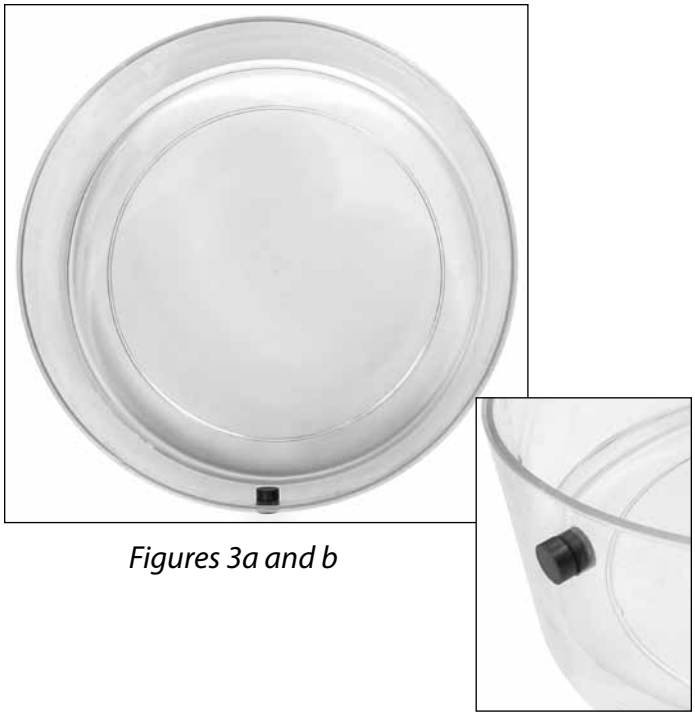
Also, be sure to have the activity area away from large masses of iron or steel (for example, steel tables, table legs, or power tools) and to keep other magnets away from the activity area.

Figure 2

In the basic configuration, water is added to the container to a depth of one inch. When several building blocks are added with the north side up, they will tend to spread away from each other and toward the sides of the container (Figure 2). This is advantageous for many activities and experiments.

Magnetic Field Configuration

In this configuration, pairs of ceramic disc magnets are placed around the container to create a magnetic field around its perimeter. For each pair of magnets, one is inside the container with the north pole of the magnet pointed toward the middle of the container and the other magnet is outside the container, also with its north pole pointed toward the center of the container (Figure 3). In this manner, the two magnets are attracted to each other through the container and hold themselves in place.



Figures 3a and b

The pairs of magnets are oriented so they are all an equal distance from each other and are about one inch from the top of the container (Figure 4 on the next page). **Note:** If different containers are used, the optimum vertical location of the magnet pairs will have to be determined by trial and error.

This orientation of magnets, with all north poles facing inward, creates a magnetic containment field within the container. The building blocks are less likely to move to the side of the container – unless other opposing magnetic forces become greater than the containment force.

Figure 4

This configuration is good for showing how external forces can be used to modify the patterns of the building blocks. In other words, showing how outside forces can control how nano building blocks can be manipulated to create specific structures.

Concept: Magnetic Forces

Students may or may not have had experiences with magnets and magnetic fields. Using the basic configuration, students can add building blocks to the container in various orientations (for example, all north side up, all north side down, some with north both down and up) and observe the results as each block is added.

Things for students to observe include:

- Like poles repelling
- Opposite poles attracting
- Shapes or patterns of building blocks with various orientations and numbers of building blocks

Students can draw conclusions based on their observations. Students can also compare these observations and conclusions with observations and conclusions from using the magnetic field configuration.

Concept: Equilibrium

The container can be considered a closed system (no external forces are exerted into this system). When inserted into the system, the building blocks will slowly orient themselves to equalize all the magnetic forces acting within the system. When the building blocks stop moving, equilibrium (where the sum of all forces is zero) has been reached.

The amount of time required for the system to reach equilibrium will vary by the orientation of the building blocks. It will also vary by whether you use the basic or magnetic containment configurations. The magnetic containment configuration has many more forces involved (each pair of magnets creates a magnetic field, and the building block magnets interact with all those fields and with other building blocks).

This can illustrate equilibrium within molecules or crystalline structures; although the actual attractive and repulsive forces involved in these are not magnetic, it provides a visualization of the process.

Concept: Self-Assembly at the Nano Scale

While students may have a rough understanding of the concept of building structures at the molecular (nano) level, this can be illustrated using the building blocks and the magnetic containment configuration.

The different building block shapes can represent various components – compounds, elements, and other substances – that are the nano building blocks for a specific structure. Just putting these elements together in the same beaker will probably not result in the desired structure. That would be like throwing 2 x 4s, wires, nails, screws, paint, carpet, and plumbing fixtures into a pile and expecting it to become a house. External forces have to guide the process in a specific order to make the pile of materials become a house.

In the same way, the use of external forces, properties of the substances, and a specific order of events can cause a pile of nano building blocks to orient themselves into a specific structure. This process is known as self-assembly. Using the magnetic building blocks, this can be experienced by the students.

Have students add various building blocks (typically no more than six) in no particular order and no particular magnetic orientation to the container. The students record the building block order, shape, magnetic orientation, and time between each addition. Have them sketch each structure that forms after the addition of each block.

Tell students to remove all the blocks and to repeat the exercise following the notes they recorded before: adding the building blocks in the same order, orientation, and time as before. If all goes as expected, the final structural shape should be the same – the building blocks self-assemble based on the forces acting within the system.

Students can also repeat the procedure using the basic configuration to determine the outcome without the magnetic containment field.

Concept: Crystal Lattice Structures

Using a rectangular container, students can add building blocks and watch as the blocks align into rows and columns in an effort to reach equilibrium.

Given the right containers and spacing, containers can be arranged vertically over each other, and three-dimensional lattice structures can be illustrated. The building blocks will interact with other building blocks within their layer, but also with building blocks in layers above and below them. By adjusting the distance between the layers, various lattice patterns can be demonstrated.

Teacher Tips

- Activities are best done with no more than three students in a group.
- Students will need a little more than one liter of water to fill the round container with one inch of water.
- When the activities are completed, students should empty the water from the container and dry all parts and pieces. You can store the materials in the container.
- The flanges on the encapsulated Nd magnets help keep the magnets in place within the building blocks. The magnets may occasionally be pulled out of the blocks by the magnetic forces. If this occurs, use the compass to determine the north end of the magnet and reinsert the magnet with its north end at the side of the block labeled "N."
- The building blocks will sometimes snap together, joining the north side of one block to the south side of the other. If this occurs, have students slide the blocks and magnets sideways away from each other so the magnets remain in the building blocks. Pulling the blocks straight apart can cause one of the magnets to dislodge from the building block.
- Repeated removal of the magnet from the building block may cause the center hole to enlarge – and the magnet may not remain in the block. If this occurs, discard the building block and replace it with one of the spares from the extra sheet of blocks. Additional magnets and sheets of building blocks are available from Pitsco.
- Be careful when handling the ceramic disc magnets as they are a brittle material and can break if dropped or snapped together.
- When using the magnetic field configuration, the height of the ceramic disc magnets on the wall of the container can be adjusted to provide different effects. If the building blocks tend to escape under the magnetic field, they will be forced to the outside of the container. If this occurs, the ceramic disc magnets need to be lowered slightly.
- Precautions should be taken to keep the magnets away from electronic equipment, especially computers, data storage devices, MP3 players, and pacemakers.

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