Magnetic Microbot Models

MATERIALS

For the activity (per pair or team)

- 1 wide-mouth, clear plastic container, at least 3 inches deep (e.g., cylindrical cover from a stack of CDs or DVDs, or a food storage container)
- 2 magnets (e.g., refrigerator magnets)
- 1 washer, not zinc-plated, 1.5 inches wide
- assortment of gadgets: paper clips (large and small); brass fasteners; washers (large and small); nuts and bolts; LED lights; small alligator clips (provide two or three of each of these items per pair)
- clear tape (double-sided, if possible) or quick-drying glue (if the magnets do not need to be reused)
- activity sheet

For the group

- 1 plate (if paper, use one with a water-resistant coating)
- ¼ cup glycerin or shampoo
- 1 toy bristlebot (e.g., HEXBUG®, available at electronics stores, or learn how to make your own at: evilmadscientist.com/article.php/bristlebot)
- video clip available at pbs.org/nova/education/makingstuff
- video display equipment

Note: The gadgets are stand-ins for robot parts, tools, and equipment. LEDs, even unlit, can be sensors and also have convenient wires for attachment. Alligator clips make great pincers or grabbers. Paper clips are easily bent into antennae, legs, and arms.

Time: Prep:15 minutes; Activity: 45 minutes

Activity Description

Kids are challenged to build a model of a small magnet-powered robot that's loaded with as many gadgets as possible, but still able to scale the wall of a container.

Learning Goal

To learn about: magnets and their properties; how materials scientists are building extremely small robots by replacing bulky mechanical parts, like motors, with magnetic materials; how materials scientists are using design ideas from nature to overcome the weird, wacky forces that tiny robots encounter.

Introduction

Materials scientists are building tiny robots that can travel inside the human body to deliver medicine or perform surgery, but there are some challenges to building small. Extremely tiny motors can be hard to build and can make the robot too big or too heavy. Also, because forces affect very small objects differently, moving through water is like slogging through mud. Materials scientists are inventing new ways to power and move micro-robots, or microbots. Some have replaced motors with magnetic materials that allow them to make robots as small as a human hair. The magnetic microbots are moved by powerful magnets located outside the body and do not require any moving parts, such as motors, gears, or wheels.

Advance Preparation

Gather the materials.

Procedure

1. Engage the kids.

Ask: *Why might scientists want to make robots that are as small as—or smaller than—an ant? What could these tiny robots do?* (Some answers are: they can go into tiny places—like inside the human body; they can scale walls; they can run on less power than big robots; they can be numerous—picture massive swarms of them exploring oceans and planets!)

Safety Notes

- Due to the use of small parts, this activity is not suitable for young children.
- Avoid parts that are sharp or otherwise pose a hazard.

2. Explore the materials.

Allow the kids to explore the magnets and other materials while you review some basic facts about magnets: Ask: *What is a magnet?* (Accept all answers.) If needed, explain:

- A magnet is an object that attracts and repels materials that contain iron, nickel, or cobalt (magnetic materials).
- Magnets exert a force (a push or a pull) on magnetic materials. This force is called *magnetic force* or *magnetism*.
- Each magnet has two poles: a north pole and a south pole. The magnetic force is strongest at the poles.
- Opposite poles (north/south) attract and like poles (north/north or south/south) repel.

3. Present the challenge.

Point out the gadgets and explain that the challenge is to build a model of a robot that can be guided and moved with no motor or other moving parts. It moves due to magnetic force. The model robot must carry as many gadgets as possible, to represent the tools and functions that a real robot would have, and still be able to climb the wall of a container.

Ask: *What parts of a robot could these gadgets represent?* (Some answers are: tiny lightbulbs could be "sensors," alligator clips could be grabbers, and paper clips could be antennae, legs, and arms.)

4. Design, build, and test the model microbots.

Allow about 25 minutes for the kids to brainstorm a design, build it, and test it. Ask them to think about:

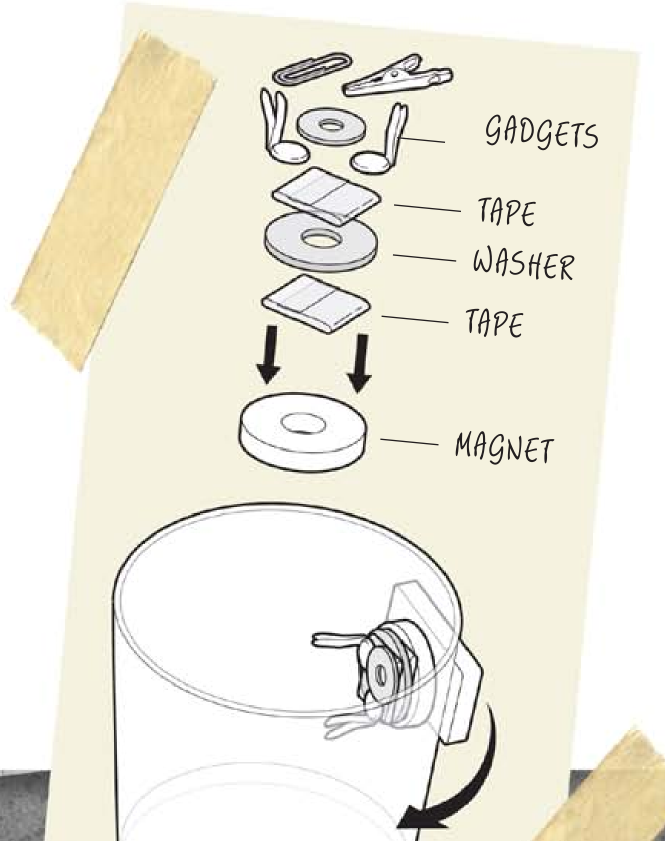
- how the size, shape, and placement of the gadgets will influence how the microbot moves (heavier or bulkier attachments will require more magnetic force to move)
- how to position the magnets to take advantage of their magnetic force (opposite poles to use attraction; like poles to use repulsion)

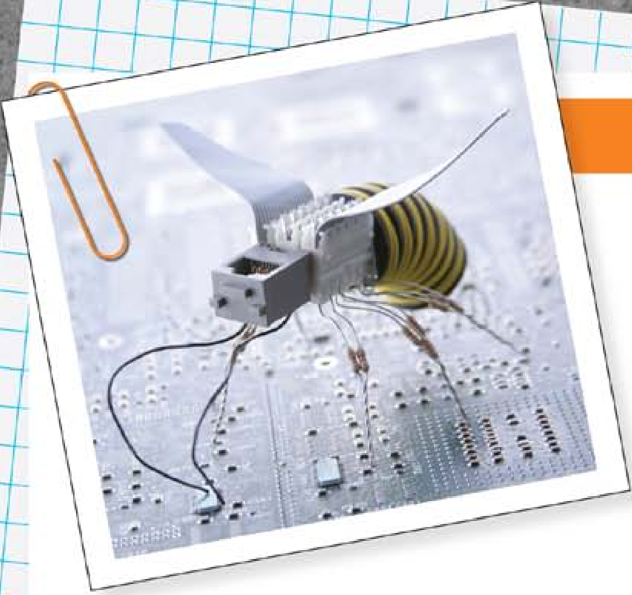
Kids may need help securely taping or gluing the materials together. One basic design is shown in the illustration. It has a washer taped to one magnet and the gadgets taped to the washer. The second magnet is used outside the container to power the robot. If a team's microbot model fails to climb the wall, encourage them to think about what went wrong and redesign their model.

5. Discuss the results.

As a group or by team, have kids present their designs. Discuss:

- *What property of magnets is used to power the microbots?* (Magnetic force, either attraction or repulsion, depending on the design.)
- *Why can the microbot defy gravity?* (The magnetic force of the magnet is stronger than the force of gravity acting on it.)
- *How many gadgets was each robot able to carry?* (Answers will vary.)





- *Which gadget materials did they choose—and why?* (Small, lightweight gadgets fit better and are easier to lift. The number of gadgets is limited by both space and weight. E.g. some real microbots must carry their own power supply in the form of heavy batteries.)
- *How could you power a robot with more tools (gadgets)?* (Use more magnets or larger, more powerful magnets to drive it.)
- *What are some other ways you could power a robot?* (Accept all answers.)

6. Conclude the activity.

Tell kids these are just a few of the challenges that materials scientists are overcoming as they design smaller and smaller robots. See some real magnetic microbots in a clip from NOVA's *Making Stuff: Smaller*, available online at pbs.org/nova/education/makingstuff. And, if time permits, present the optional extension demonstration on how the world is a very different place when you're microscopic.

EXTENSION DEMONSTRATION

Q: When is moving through water like swimming in mud? **A:** When you're microscopic!

Advance Preparation

Pour the glycerin onto the plate. Make sure the bristlebot is working.

1. Engage kids.

Ask: *Think about how you move through water in the bathtub or a swimming pool. Is it hard for you to push it out of the way with your body or hand?* (No. The water offers some resistance but kids are big enough to overcome it.)

2. Think small.

But what do you think it would be like if you were very, very small? (Accept all answers, then explain it would be like trying to swim through mud or quicksand. Very small organisms or objects, like bacteria or microbots, are not able to overcome the resistance of the water. To them, the water is very viscous, like syrup or molasses is to us. It resists flow. A bacterium is a million times smaller than a human, so, to it, the water is a million times more viscous or resistant to flow.)

3. Demonstrate the bristlebot.

Turn on the bristlebot and let it move around the table. Say: *This is what it is like for this toy robot to move in air. Air is much less viscous than water.* Place the bristlebot in the glycerin; it will not move much, but will continue to vibrate. *For very small objects or organisms, this is what it is like to move through water.*

4. Conclude the demonstration.

Explain: In nature, tiny organisms have evolved different ways to deal with this problem. For example, some bacteria have whip-like tails called flagella that swivel around to push them through the water. Materials scientists often take ideas from nature to solve engineering problems. For example, one microbot that has been designed is shaped like a tiny corkscrew or spring, just like a flagella. Magnets cause it to spin to propel it. It could one day swim through the bloodstream to deliver medicine or perform surgery. Download and view the NOVA *Making Stuff: Smaller* video clip at pbs.org/nova/education/makingstuff to see some real magnetic microbots.

A bristlebot moving through glycerin demonstrates the difficulty that small organisms or objects have moving through water.

MAKING STUFF

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NOVA PBS

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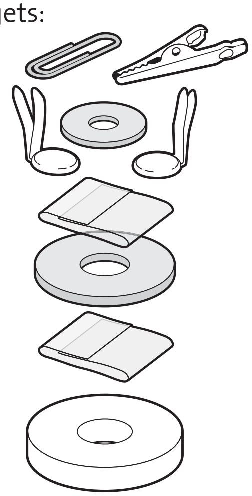


- clear tape (double-sided, if possible) or quick-drying glue (if the magnets do not need to be reused)

Tiny robots could travel inside the human body to deliver medicine or perform surgery, but it's difficult to build very tiny motors with enough power. Some materials scientists are replacing motors with magnetic materials so they can use magnetic force to power the microbots from a distance. **Design and build a small robot powered by magnets. It must carry as many gadgets as possible and still be able to climb the wall of a container.**

1. Brainstorm a design for your magnetic microbot model and sketch it here.

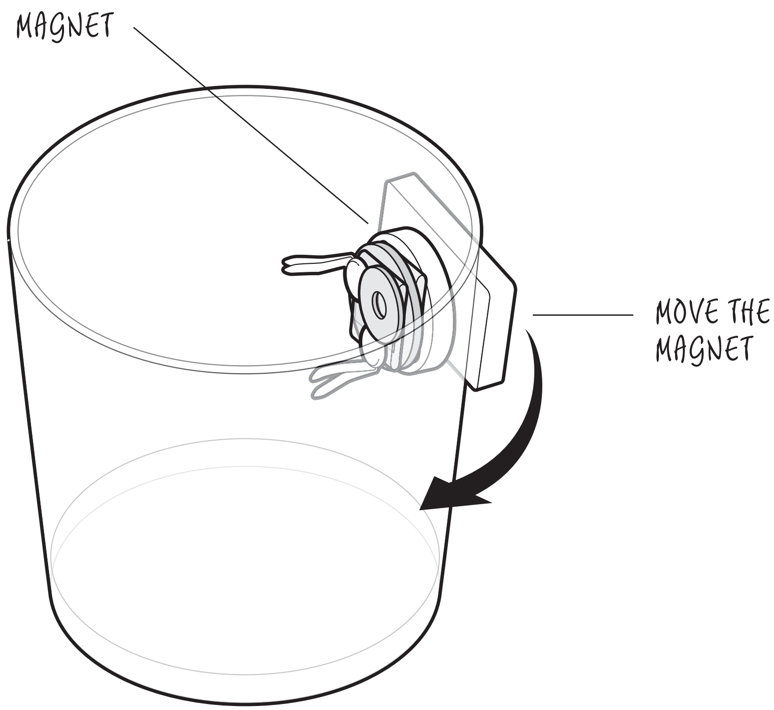
The gadgets are stand-ins, or models, for the parts and tools that a real robot would have. What robot part or tool could the tiny lightbulbs represent? What about alligator clips? Paper clips? Brass fasteners?

2. Brainstorm how to power your microbot.

Think about how you can use the properties of magnets to power your microbot. Remember, opposite poles (north/south) attract and like poles (north/north or south/south) repel.

3. Build your magnetic microbot model and test it.

Place the robot inside the container and test-drive it. Can you control how it moves? Can it climb the walls of the container? If not, make design changes and repeat the test.



4. Think about your results.

- Why do magnets move your microbot?
- How does the microbot defy gravity?
- How many gadgets was your microbot able to carry?
- Which gadget materials did you choose and why?
- What design changes would you have to make to power a robot carrying even more tools (gadgets)?

5. Think like a materials scientist.

What are some other ways you could power a tiny robot?

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