Name: Date:

# Creating a Compass from a Magnet - Teacher Guide

**Setting the Stage**

In this lesson students create a compass and apply their reasoning about magnetism to how compasses work to help us navigate around the globe while utilizing the Earth's magnetic field. It may be included in a unit on the Earth's interior.

Photo credit: 2009 howstuffworks.com

**Lesson Overview**

- *Activity 1 – Engage (15 minutes) How does a compass work?*
  Engage students in discussion about how compass works.
- *Activity 2 – Explore (30 minutes) Create a compass*
  Students each create a compass.
- *Activity 3 – Explain (15 minutes) Class discussion*
  Students analyze the results of their exploration, and create a model and explanation for how a compass works.
- *Activity 4 - Elaborate (30 minutes) Navigating Animals*
  Students research and make a poster about how organisms use magnetoreception to navigate.
- *Activity 5 - Evaluate (15minutes) Putting it all together*

As an assessment, students write about and draw models of what they learned in this lesson

| Instructional Overview | |
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| **Grade Level** | Upper Elementary/Middle School |
| **Instructional Time** | 1 hour and 45 minutes |
| **NGSS Standards Alignment** | MS-PS1.A Structure and Properties of Matter<br>MS-PS2.B Types of Interaction |
| **Learning Goals** | ● Conduct an investigation to learn about magnetism<br>● Analyze results to determine the difference between a temporary and permanent magnet<br>● Apply results to the creation of a magnetic compass to be used to determine direction relative to the Earth's magnetic field |
| **Materials** | ● 3+ compasses to pass around the class<br>● Sticky notes (2in x 2in) - enough for each student to use multiple<br>● Model or image of the Earth's interior with layers and composition labeled<br>● Plastic Cups (one per pair of students)<br>● Large Pitcher for distributing water<br>● Paper (scrap paper is good)<br>● Scissors<br>● Paperclips (must be metal, one per pair of students)<br>● Magnets (two per pair of students): ring or bar magnets<br><br>Note: Magnets can be obtained from various online science supply retailers, while the other materials are easily obtained from an office supply store. |
| **Material Preparation** | This lesson requires very little preparation. The teacher should practice making the compass on their own ahead of time, so they can give students tips. This can be done ahead of time in about 15 minutes. |
| **Vocabulary** | Magnetic field: The invisible force exerted by a magnet on other magnetic objects<br>Temporary magnet: An object that has a temporary magnetic field |

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|---|---|
| | Induced magnetism: Occurs when a temporary magnet is created<br>Magnetic domain: Small areas of matter within which the unpaired electrons of atoms are aligned with one another (these all align with one another in a magnet)<br>Magnetic poles of the earth: The location where the magnetic field exits (north) and enters (south) the earth<br>Geographic poles of the earth: The traditional north and south pole we typically think of |

**Activity 1 (Engage)**

How does a compass work? (15 minutes)

**Background information**

Magnets are attracted to other magnetic metals (e.g. iron, nickel, cobalt). Magnetic metals are similar in that they have unpaired electrons orbiting their atoms. When these electrons align in a certain formation, the metal becomes magnetized. The alignment of atoms occurs within magnetic domains, which are small areas of matter within which all of the unpaired electrons are aligned in a similar manner. When a magnet is formed, these magnetic domains become aligned in the same direction relative to one another (Figure 1).

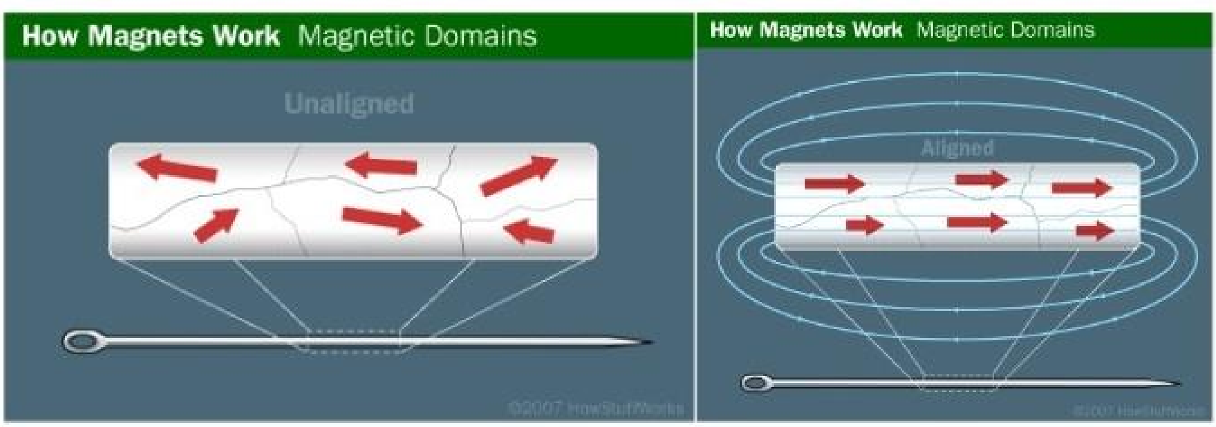


Figure 1. A needle is normally not a magnet because its magnetic domains are not aligned (left). When a needle contacts a permanent magnet for an extended time (or is rubbed along a permanent magnet), its magnet domains align in the same direction, forming a temporary magnet with a magnetic field (right). (Images from www.howstuffworks.com).

While students may not be aware of atoms and electrons, they can easily grasp the concept of areas within the metal lining up within one another. When the areas (i.e. magnetic domains) are no longer aligned, the temporary magnet is no longer a magnet. In permanent magnets, the magnetic domains are always lined up with one another. Over time, a temporary magnet will lose its magnetism as the domains become unaligned. This process can be sped up by physically jarring the magnet (e.g. banging it against a desk).

The Earth itself has a giant magnetic field that is strong enough to be measured by sensitive instruments. The field is generated by the movement of molten rock (containing iron) within the center of the Earth. The Earth's magnetic field is very weak relative to the gravitational field. If the Earth is thought of as a giant magnet, its north pole is actually the geographic south pole and its south pole is actually the geographic north pole (Figure 2). The magnetic south pole is called the geographic north pole because the north pole of a magnet will align with it (north and south poles attract).

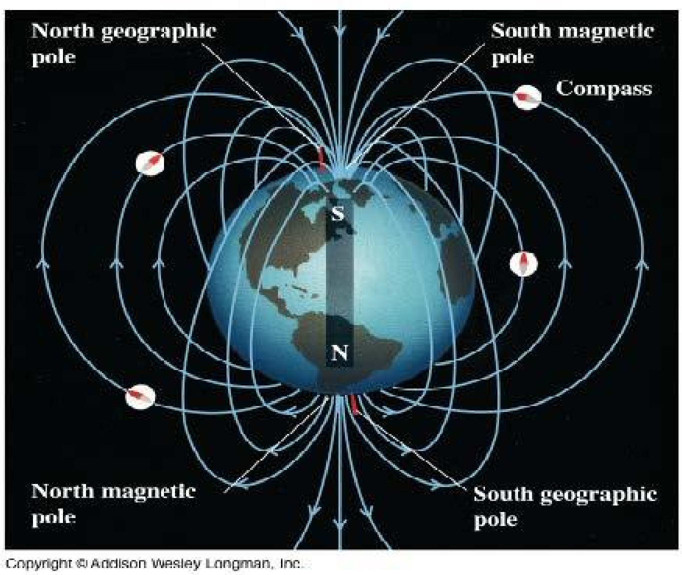


Figure 2. The magnetic poles of the earth are opposite to the geographic poles. The lines represent the direction of the earth's magnetic field.

A compass is simply an elongated magnet that is suspended in a way that allows it to move freely. The magnet will align with the earth's magnetic field (i.e. the north pole of the magnet will point to the magnetic south pole of the earth). This allows one to use a magnet for navigation.

**References:**

http://science.howstuffworks.com/magnet.htm
http://www-spof.gsfc.nasa.gov/Education/Intro.html

**Activity 1**

Most students do not realize that a compass needle is a magnet and that the Earth has its own magnetic field. Begin this lesson by passing around a few compasses while mentioning that a compass is used to navigate around the Earth.

> Pose the question, "How does a compass work?" Ask students to place their idea on a sticky-note.

Allow students to share their ideas while collecting their sticky-notes, and placing them on the front board for everyone to see. Once all students have shared their ideas, ask one or two students to create clusters of sticky-notes that share similar ideas. This is a time to hear what the students know about these topics, but not to give away the answers. Mention to the students that their ideas will be explored during the lesson. Suggest that we can discover how a compass works during the following investigation.

**Activity 2 (Explore)**

Create a compass (30 minutes)

Refer to the ideas the students generated in *Engage*. Provide pairs of students with two magnets to explore. Ask students to record three or more observations about how the magnets interact, and how those observations that may assist in figuring out how a compass works.

After 5 minutes ask students to share their results. Highlight the observations students made that contribute to a model of how a compass works. Ask students if all materials can act like magnets do. If this was not revealed in a previous lesson, mention that magnetism is a physical property of some materials, but not all.

Ask students what they recall about the composition and structure of the Earth's interior. Present students with a model of the Earth's interior with composition of the inner and outer core identified. Ask students to compare the material found in a magnet to the composition of the inner and outer core of the Earth. Collect their ideas, and focus their attention on the magnetism generated from the Earth's outer core, and that magnetism is what allows compasses to work on the surface of the Earth.

Ask students how they might be able to create a compass, and what types of materials would be needed. Based on the discussion, they should recognize that they need a magnet that will be attracted to the magnetism of the Earth. However, they may not know that they can create a magnet. Present students with Figure 1 which shows how magnetism can be induced in a metal, and mention that they can do the same thing.

Present pairs of students with materials to make their own compass: a plastic cup filled with water, one paper clip, a small piece of paper, and one magnet from the previous part of this lesson. Ask students if they have an idea how we can make a compass with these materials? You can lead them into the right configuration as a class.

The best way to construct the compass is as follows:

- Cut out a small piece of paper (2 x 2 cm) and float it on top of the water inside of the cup.
- Rub the magnet on one end of the paperclip for about 30 seconds (it's important that the students only touch one end of the paperclip to the magnet for best results). Refer students to the figure to identify the purpose of this step.

- Float the paperclip on top of the piece of paper in the cup, allowing the paper and the clip to move freely (i.e. it shouldn't be stuck against the side of the cup). Students must be very gentle to avoid having their paperclip sink.
- Tell the students to keep their magnet away from paperclip once it is floating on the paper (they can investigate how the magnet makes the paper clip move around later)

Once the majority of the students have floated their paperclip (some will need several tries to avoid it sinking), ask the class, "Which direction is your paperclip pointing?" Have one student act as a data collector, who will tally the number of students whose paper clip is pointing in a similar direction. Point to each of the four walls of the classroom, and have students raise their hand if their paperclip is pointing towards that direction. The majority (probably not all, due to methodological inconsistencies) of the students should raise their hand when you point to the walls that are perpendicular to the north-south axis. The data collector can make a data table showing the direction of the paperclips within each student's cup. Each student should transcribe the data table into their notebooks.

Refer to the sticky-notes from the *Engage*, and ask students if any of their ideas were supported.

**Activity 3 (Explain)**
Class discussion (15 minutes)

Debrief the results from the data table. Students should note the patterns in the data. Ask students what they think is occurring. Bring up the point that most of the paperclips aligned with the north-south axis. Why did this happen? What happened to the paperclip? By this time most of the students will have realized that the paperclip became a temporary magnet.

Students may not make the connection between their temporary magnets and the Earth's magnetic field. Mention that a freely moving magnet will align with the Earth's magnetic field. Ask students to draw a model in their notebooks that shows the relationship between their temporary magnet and the Earth's magnetic field. Their models should show the alignment between the paperclip and geographic north. Ask them to create an explanation using the evidence from the data table to explain how a compass works. Ask students to share their models and explanations.

The main take home concepts are as follows:

> The paperclip became a temporary magnet when we rubbed the permanent magnet against it. This happens when the magnetic domains of the paperclip align with one another. These domains can become misaligned over time, or by physically jarring the paperclip (this is why the paperclip is a temporary magnet and not a permanent magnet).
>
> Once the paperclip is magnetized, it exerts a magnetic field which aligns with the earth's invisible magnetic field. The north pole of the temporary magnet (i.e. the paperclip) points in the direction of the magnetic south pole, because opposite poles attract (remember, the magnetic south pole of the earth is actually the geographic north pole of the earth - this can be confusing to students).
>
> The Earth has its own magnetic field as a result of the flowing movement of molten rock, containing iron, that exists deep within the earth's core.
>
> For older students: The Earth's magnetic field is dynamic, meaning it's constantly changing. The exact location of the north and south magnetic field is slowing moving. In fact, the polarity of the earth's magnetic field has actually reversed completely many times in geologic history! The Earth's magnetic field is important to life on earth because it protects us from cosmic rays.

**Activity 4 (Elaborate)**

Navigating Animals (30 minutes)

Now that students have an understanding of how humans can use compasses to navigate, ask them how animals know how to migrate from place to place. They may not make the connection between their compass exploration and animal navigation. Many organisms can detect the Earth's magnetic field to perceive direction, altitude, and location, and this is called magnetoreception.

Show and discuss one of these videos (or another one) on magnetoreception:

- Animal Magnetism: How Animals Navigate
- How Do Animals Find Their Way Home Without GPS?
- We Don't Know: Magnetoreception

Ask pairs of students to research an animal (each team should select a different organism) that uses magnetoreception for navigation, and create a small poster to share this information with their classmates. Their research and poster should include information about how the animal uses magnetoreception to get from one place to another.

Use a gallery walk routine to present student's posters. Students can leave sticky-notes on the posters in one of these messages: I notice…, I like…, I wonder…

Close this part of the lesson with a class discussion of the patterns saw in the posters from one animal to the next.

**References:**

Lohman, K. J., C. M. F. Lohman, L. M. Ehrhart, D. A. Bagley and T. Swing. 2004. Animal behavior: Geomagnetic map used in sea-turtle navigation. Nature 428: 909-910.

Holland, R. A., J. L. Kirschvink. T. G. Doak and M. Wilkelski. 2008. Bats use magnetite to detect the Earth's magnetic field. PLoS One 3: e1676

**Activity 5 (Evaluate)**

Putting it all together  (15 minutes)

To assess students' learning, consider having them complete a short writing assignment with drawings that includes the following:

- ❏ Earth's interior (structure and composition)
- ❏ Earth's magnetic field
- ❏ How a magnet works
- ❏ How a temporary magnet is created
- ❏ How a compass works