



Lesson Title: Making a Compass

NSF GK12 Fellow: Dan Preston (Boulder, CO)

Grade Levels: 3 - 6

Type of Lesson: STEM

Objective: To have students understand 1.) what a temporary magnet is, 2.) how a temporary magnet is created, 3.) that the earth has a magnetic field, 4.) what causes the earth's magnetic field and 5.) a compass is a magnet that aligns with the earth's magnetic field. This lesson applies to the following BVSD Essential Learnings:

Science Standard 2: Students know and understand common properties, forms, and changes in matter and energy.

Science Standard 4: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.

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 (Fig. 1).

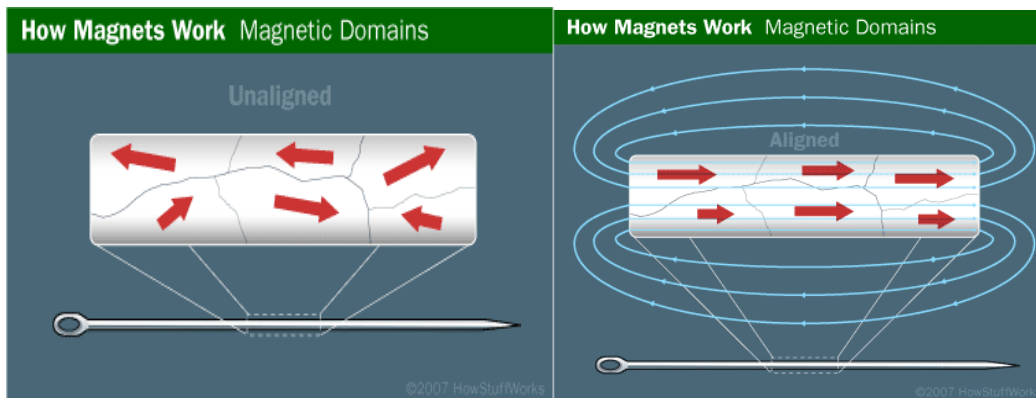


Figure 1. A needle is normally not a magnet because its magnetic domains are not aligned (left). When a needle contacts a permanent magnet for an extended time (or is rubbed along a permanent magnet), its magnet domains align in the same direction, forming a temporary magnet with a magnetic field (right).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

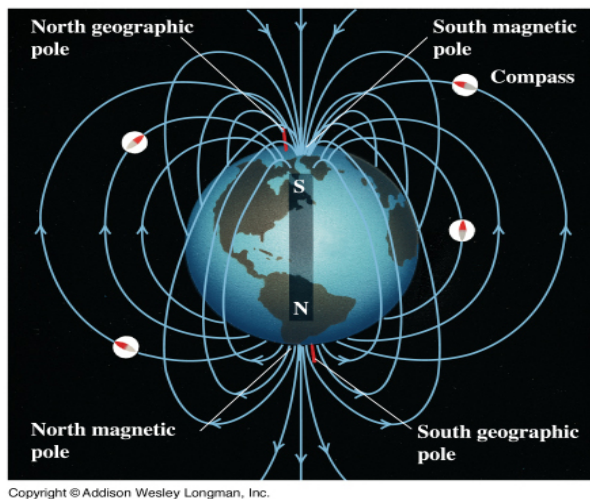


Figure 2. The magnetic poles of the earth are opposite to the geographic poles. The lines represent the direction of the earth's magnetic field.

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 magnet 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>>

Lesson Vocabulary:

Magnetic field: the invisible force exerted by a magnet on other magnetic objects

Temporary magnet: an object that has a temporary magnetic field

Induced magnetism: occurs when a temporary magnet is created

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)

Magnetic poles of the earth: the location where the magnetic field exits (north) and enters (south) the earth

Geographic poles of the earth: the traditional north and south pole we typically think of

Material Required:

Plastic Cups (one per student)

Large Pitcher for distributing water

Paper (scrap paper is good)

Scissors

Paperclips (one per student)

Magnets (one per student, ceramic donut magnets work, but neodymium magnets are better)

Magnets can be obtained from various online science supply retailers, while the other materials are easily obtained from an office supply store.

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.

Safety Information:

If neodymium magnets are used, students must be careful not to let them slam together (this can pinch fingers). Magnets must never be allowed near electronics, as this can damage them.

Engagement:

Begin by posing the question, "How does a compass work?" Most students have not realized that a compass needle is a magnet and that the earth has its own magnetic field. This is a time to hear what the students know about these topics, but not to give away the answers. Suggest that we can discover how a compass works during the following investigation.

Exploration:

Lead the students in a classroom activity where each student makes their own compass out of the materials provided (one plastic cup full of water, one paper clip, a small piece of paper, and one magnet). First pose the question, "Does anyone 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:

- 1.) cut out a small piece of paper (2 x 2 cm) and float it on top of the water inside of the cup.
- 2.) 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)
- 3.) 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 gently to avoid having their paperclip sink.
4. 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 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 T-chart showing the direction of the paperclips within each student's cup. Each student can draw this T-chart into their own science notebook.

Explanation:

Start by asking the 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. Fewer students will realize that the earth has its own magnet field that a freely moving magnet will align with. Help the students come to this conclusion using a discussion of the data in their T-charts. The main take home concepts are as follows:

- 1.) 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).
- 2.) 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).

3.) The earth has its own magnetic field as a result of molten rock, containing iron, that exists deep within the earth's core. The earth's magnetic field is dynamic, meaning it's constantly changing. The exact location of the north and south magnetic field is slowly 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. The following URL provides a video (narrated by Bill Nye the Science Guy) with more details on the earth's magnetic field:

<<http://videos.howstuffworks.com/science-channel/29143-100-greatest-discoveries-earths-magnetic-field-video.htm>>

The video can provide a nice complimentary component for a discussion on the earth's magnetic field.

Extension:

A fun way to extend this lesson is by discussing and giving examples of how animals make use of the earth's magnetic field to navigate. Many species, including migratory birds, sea turtles and bats, are able to sense the direction of the earth's magnetic field so that they can navigate over long distances. It is thought that these animals have a sort of compass inside their bodies, perhaps with magnetite acting as the "needle" within a very specialized sensory organ. Scientists have demonstrated this ability using clever experiments. Two scientific articles that can be discussed (or allow the students to read them and explain the results to the class) are below. These can be accessed online, or through a university library:

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

Evaluation:

This can be done in multiple ways, but I prefer using a short written assignment where the students respond to a conceptual question about the lesson a day or two later. For example, a broad question might be: How does a compass work?

Wrap-up: I like to end the lesson in a discussion format by reviewing all of the learning objectives one at a time. These can be summarized on the board and in the student's science notebooks. This often takes longer than expected, so leaving 15 minutes for this is a good idea.