Magnets and Compasses

Adapted from education.com "How Does a Compass Work?"

You are lost in the wilderness. You know there is a highway several miles north of you, but you don't know which direction north is. Luckily, you have a magnet with you! How can you find your way using your magnet?

Problem:

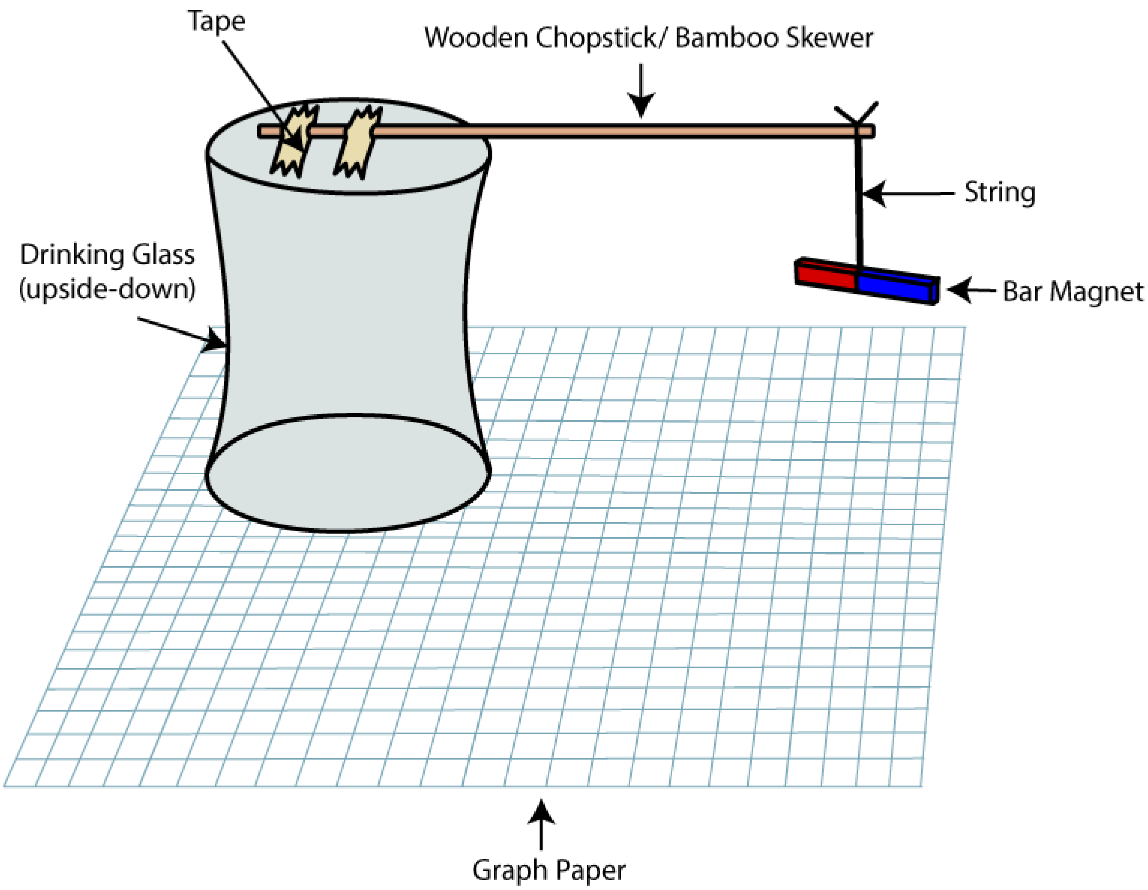
How does a compass work?

Materials:

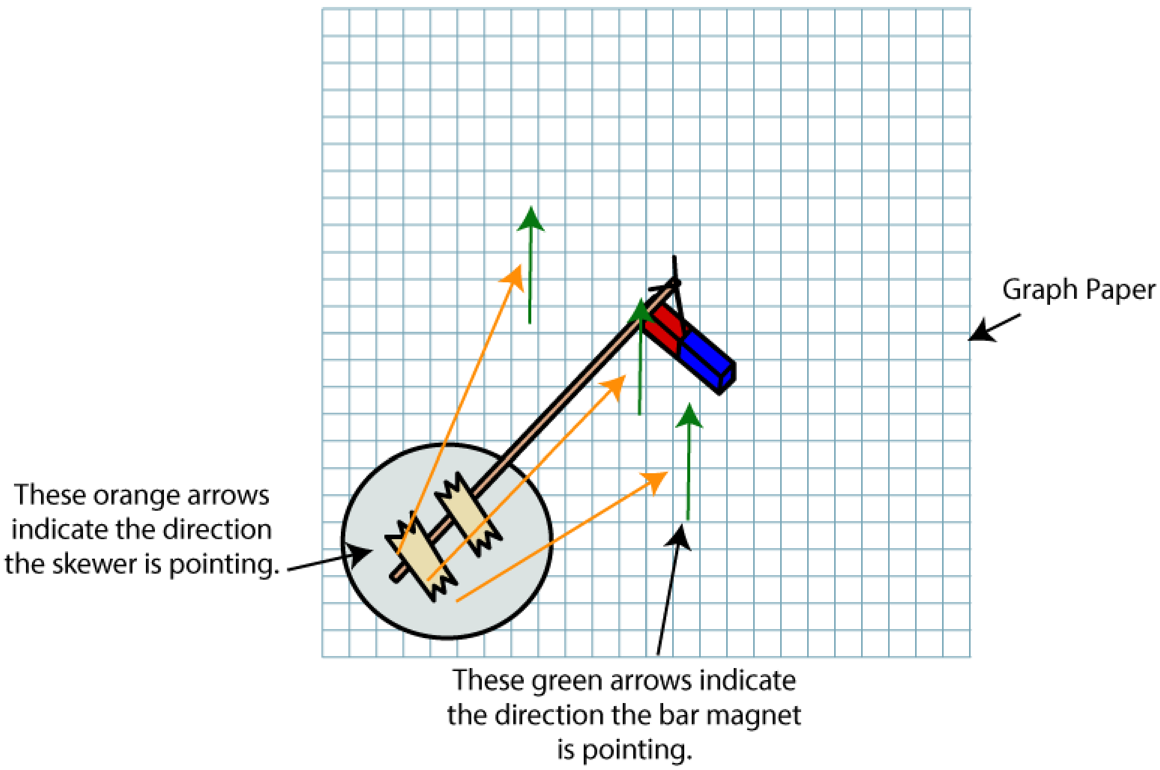
- Skewers
- Plastic cup
- One small bar magnet
- Thread
- Something to write with
- Paper
- Tape
- Iron filings (only for second part)

Procedure:

1. Turn your cup upside down.
2. Take one skewer and place it on top of your upside down cup. Make sure one end of the skewer is hanging over the edge of the cup.
3. Tape your skewer in place.
4. Take a look at your small bar magnet. If it doesn't have its ends labeled, mark one end so you know which is which.
5. Tie a string around the middle of the Small Bar Magnet. Tie the other end of that string to the end of the skewer hanging over the edge of the cup. Make sure the small bar magnet is far enough above the table that you can draw under it.
6. Put the assembled compass in one corner of a sheet of graph paper. Trace a circle around the bottom of the cup. You may have to hold the cup down with your hand if the magnet is too heavy.



1. Keeping the bottom of the cup in the circle you drew, turn the compass so the small bar magnet hangs near one edge of the graph paper.
2. Use your marker to make a mark on the graph paper under the spot where the skewer meets the edge of the cup. Make another mark underneath the end of the skewer.
3. Connect these marks to indicate the direction that the skewer is pointing in.
4. Wait for the Small Bar Magnet to stop moving. Once it's still, draw an arrow underneath the bar magnet in the direction the magnet's mark is facing.
5. Without moving the paper, rotate your compass so that the skewer points in a new direction. Repeat steps 8 and 9. Remember to let the small bar magnet stop moving before you draw any arrows.



1. After you have three or more arrow pairs drawn, take note of the directions the arrows are pointing. *What do you notice?*

Results:

All the arrows should point in the same direction. This direction is either north or south, depending on which end of the small bar magnet you marked. Extra credit: Since the end of the magnet that points north is defined to be the north pole of that magnet, which pole of the Earth's "magnet" must be near the geographic north pole?

Why?

Compasses have small magnets in them that rotate to match the earth's magnetic field. That's right—the whole planet acts just like a giant magnet! You're around four thousand miles away from the center of earth's magnetic field, a distance greater than the distance across the entire United States. Not only is the earth's magnetic field powerful enough to move your magnet—it's even powerful enough to move particles around in space. That's where the *aurora borealis* comes from.

Our bar magnet is made of iron, a metal with a special property called **ferromagnetism**(Fair-O-Magnetism). This means that whenever iron is close to a magnet the magnet will **induce**, or make, the iron into another magnet that faces the opposite direction. This is how objects made of iron are able to stick to a refrigerator. The surface of the refrigerator acts as a large magnet that interferes with your compass' direction. In addition, most refrigerators use magnets to hold them shut. If your compass gets close to either one of these sources of magnetism, it will react to that source's magnetic field instead of the Earth's magnetic field.

If you have time

1. All you need at this point is the magnet, the paper, the iron filings, and something to write with. Untape the bar magnet from the skewer.
2. Lay the paper on the table and spread some iron filings out on it.
3. Lay the magnet down in the middle of the pile of filings. The filings should trace out the magnetic field lines generated by the magnet.
4. Carefully pick up the magnet, minimizing disturbance of the filings.

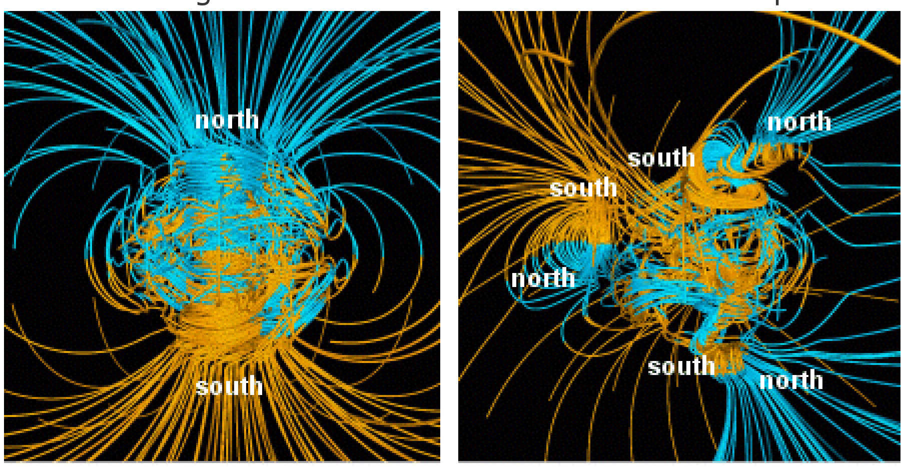
What's going on here? The iron filings have organized themselves along the lines of the **magnetic field** of the magnet. All magnets make an invisible magnetic field in the space around them that affects other magnetically active objects in the vicinity. These lines are how magnets "talk" to other magnets, including the Earth. The Earth also makes magnetic field lines just like our magnet, but those field lines stretch all the way from the north pole to the south pole. So even though the magnet and the Earth aren't touching when the magnet is hanging from the skewer, the magnetic field of the Earth and the magnet are "touching". The magnetic field lines like to all point in the same direction, and so that's why the magnet always turns to point north/south.

Fun facts about magnets and the Earth

- The magnetic poles of the earth are not aligned with the geographic poles (which are defined by the rotation of the Earth).
- Since the north pole of a magnet points north, that means that the north pole of the Earth's magnet is actually near the geographic south pole, and

the south pole of the Earth's magnet is near the geographic north pole! Specifically, the south pole of the Earth's magnet is in the Arctic Ocean just south of the geographic north pole, and the north pole of the Earth's magnet is just off the coast of Antarctica. Confusingly, people still use the words "magnetic north" to refer to the pole near the geographic north pole, and "magnetic south" to refer to the pole near the geographic south pole.

- The magnetic poles move! In fact, magnetic north (near Canada) has recently been moving about 30 miles northwest each year.
- The poles actually reverse direction! This doesn't happen very often, maybe every few 100,000 years, but when it does, it's probably pretty crazy! We're not entirely sure what it's like because it has never happened in recorded human history. The last one was about 780,000 years ago. The picture below is a computer simulation of what the field lines might look like during a pole reversal. There might be more than one north and south pole!



between reversals | during a reversal

- We know this happens because when magnetic lava cools into rocks, the rocks turn into magnets with fields that point the same way as the Earth's field. But some old rocks have fields that point opposite of newer rocks, so if you can figure out how old the rock is, you can guess which way the Earth's magnetic field was pointing when it cooled from lava into a rock.

Disclaimer and Safety Precautions