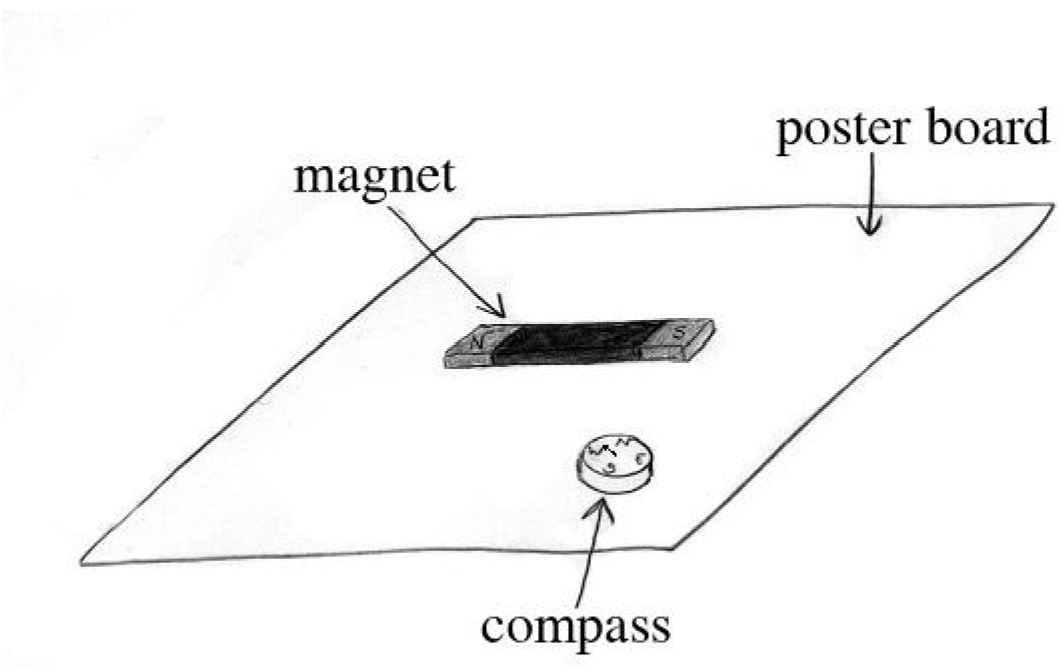
Tesla's Domain: Magnetic Fields

Commentary/Inquiry

We will explore ***magnetic field*** configurations and ***field strengths*** for permanent magnets in this exercise. We will use the following: a strong bar magnet, several smaller "stackable" magnets, a small compass, a battery in a holder and a piece of wire, a sheet of poster board, and a ruler. If one is available, use a thick-walled copper pipe and neodymium magnet or magnets.

1. Choose a horizontal workspace that is as free as possible from stray magnetic fields or steel. Your instructor may ask you to slip a piece of iron or steel at a particular position under the posterboard to observe the effect on the field. Place a strong bar magnet on a piece of posterboard. Make sure that the north pole points toward one end of the posterboard and the south towards the other (see illustration).



Avoid placing the magnet on the cardboard in such a way that the poles are on the top and bottom of the magnet or you will get nonsense (some rectangular magnets have their poles on the large,, flat sides rather than the ends)!

Place a small compass next to one corner of the magnet. Make a dot on the posterboard near the **back** end of the needle pointing toward the magnet and the **front** end (pointing away) as well. Now move the compass forward so the dot which was at the front is now at the back and end of the needle and make a new dot at the front end. Repeat this process until you return to the magnet again.

Drawing a curve through the dots should yield a “loop” in the magnetic field, or **points for which the field has equal strength** (think: topographic map). This line is sometimes called “a line of force” and is a tool used to visualize fields.

- The lines are referred to as “imaginary”. You can see yours, though.   What have you done to make it “visible”?

- Start at several points over the magnet to trace out several loops (at least six for each end, or pole). Does the field look as you had expected?

- If there were any unexpected deviations from your prediction(s), how might you explain them? Can you infer what the field looks like for the other side or end using symmetry?

2. If you have several magnets, you can explore field strength as a function of the number of magnets and the distance from a magnet.

- Experiment with varying the number of magnets and varying the distance between the compass and a magnet or magnets. When using multiple magnets, be sure to stack them so they reinforce one another, south pole to north pole, etc. Place the compass on a surface in a manner that the needle points in a direction that is **perpendicular** to the north-south axis of the magnet. For example, if the compass points from S to N, place the magnet in an E-W orientation. The original orientation of the compass needle is due to the Earth's magnetic field. We want the field due to the magnet to act at right angles to this; so by looking at the angle from North, we can estimate the relative strength of the magnetic field due to the permanent magnet as compared to the earth's field.

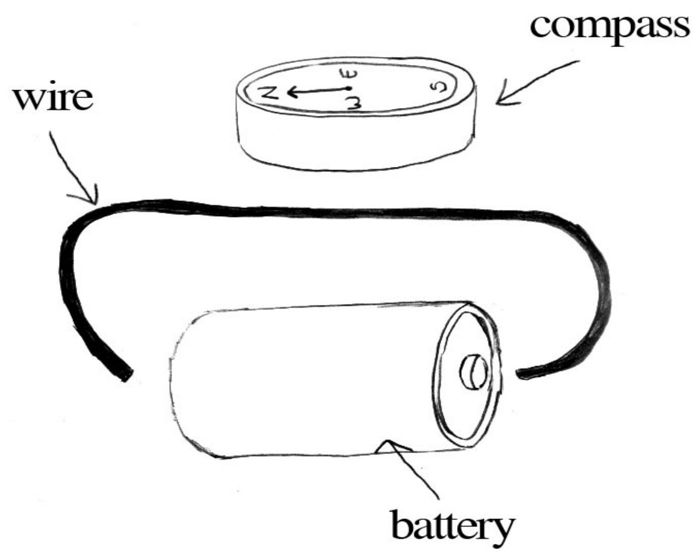
- If the distance from the compass to the pole of the magnet or magnets is doubled, how many magnets are required to turn it from its original position through the same angle?

- What if the distance is tripled?

- Now, place a single magnet perpendicular to the axis of the compass again so that the needle is deflected by an angle of about 5-10 degrees. Add magnets in a stack and record the angle of deflection as a function of the number of magnets. Is the angle proportional to the number of magnets? If not, can you explain why not? (think about why the magnet is pointing in its original direction and see "May the Force be With You").

3. Finally, place the compass next to a horizontal wire that is carrying a current (the wire will have to be connected to a power source (a flashlight battery works fine). Only leave the wire connected long enough to see what happens and disconnect immediately afterward

and **NEVER** try this with a wall outlet!). You can use the connection to the battery as a switch. The compass needle should point parallel to the wire when no current flows if you have it oriented correctly. Your instructor will help you to find a way to vary the current in the wire if you are to do so.



- Keep the current fixed and slowly move the magnet away from the wire. You must hold the wire steady in the vicinity of the wire. Placing the compass on a book so the edge of the compass is near or touching the wire may help. How does the angle vary with distance form the vertical wire? Do you a similar dependence of angle on distance for a permanent magnet?

- Holding the distance constant, does the angle change if you add another battery in series with the first? If so, what changes occurred?

- *(Optional:)* How does the angle that the compass needle makes vary with current? (You must have the ability to do this and measure the current) This time, hold the distance from the wire to the compass constant.