How the Strength of a Magnet Varies with Temperature

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Experimental Procedure

Preparing Your Work Area and Tools

Caution: Here are some general safety guidelines you should read before you do this project.

1. Always use tongs or thick, insulated gloves for handling magnets at extreme temperatures.
2. Practice handling the magnet using tongs and thick, insulated gloves at room temperature before heating or cooling your magnet.

1. You will test your magnet at four different temperatures:
    a. Approximately −20 °C (the temperature of your freezer)
    b. 0°C (the temperature of a water ice bath)
    c. Approximately 20 °C (room temperature)
    d. 100 °C (the temperature of boiling water)
2. You will use the amount of paper clips that the magnet can pick up as a measure of its strength.
    a. Because your magnet might pick up quite a few paper clips, you will not count the number of clips, but will use their total mass, expressed in grams (g) as your unit of measurement.
3. Copy the following data table in your lab notebook. It will be used to record your measurements.

	Freezer	Ice/Water Bath	Room	Boiling Water
Temp (°C)				
Trial 1 (g)				
Trial 2 (g)				
Trial 3 (g)				
Trial 4 (g)				
Trial 5 (g)				
Average (g)				

Table 1. Make a data table like this one in which to keep track of measurements. You will record the measured temperature in the second line and the measured mass of paper clips picked up by the magnet for each trail in the following lines.

4. Practice measuring the strength of the magnet:
    a. It is important to perform *exactly* the same procedure for each trial. You will practice and optimize your procedure in this step.
    b. With your magnet at room temperature, follow the procedure described in Measuring the Magnet Strength (#measuring_strength), below, and measure the magnet strength (the amount of paper clips picked up) a couple of times. Note that small variations in your measured results are to be expected. Scientists call these *statistical fluctuations*. Your job is to pay attention to ways you might *introduce* variations and find ways to eliminate those as much as possible.
    c. Here some ideas of ways you might introduce variations to get you started:
        i. Bringing the magnet down sideways for one trial and flat for another introduces variations in your measurements. Bring the magnet down the same way each time.
        ii. Picking the magnet up with insulated gloves for some trials and bare hands for others can introduce variations in your measurements. You might push off more paper clips when using insulated gloves. Use your gloves for all trials, even the trials at room temperature.
        iii. Different ways of piling the paper clips can introduce variations in your measurement. Create a flat-top pile—at least 2.5 cm (approximately 1 inch) wider than your magnet—for each trial.
5. Once you feel confident that you can make reliable measurements, go to the section Taking Measurements at Various Temperatures (#measurements_temperatures), below.

Measuring the Magnet Strength

1. Create a pile of paper clips like the one shown in Figure 3, below. You can do this on a flat surface (as in Figure 3) or on a plate (as can be seen in Figure 4, below). The pile needs to be at least 1 inch wider than your magnet on each side of the magnet. Make sure the top of the pile of paper clips is flat.

Figure 3. A flat pile of paper clips will be used to measure the strength of a magnet.

2. With your insulated gloves on, hold your magnet above the pile.
3. Lower the magnet down slowly until it rests in the middle of the pile of paper clips, as shown in Figure 4, below.

Figure 4. The magnet rests on a flat pile of paper clips that were originally placed as a flat pile on a plate or flat surface. The number of paper clips it picks up when removed is a measure of the strength of the magnet.

4. Now, slowly remove the magnet from the pile. Ideally, you should not add or remove any paperclips stuck on the magnet with this movement. It is ok, though, if you need to push off some paper clips that are stuck to the magnet to remove the magnet from the pile, or to pinch off additional paper clips, as long as you make sure you use the same movements with every measurement. Try not to pick up extra paper clips that are not stuck to the magnet though.
5. Zero out your scale so it indicates 0 g when the container you are using to measure (your measuring boat) is on the scale. *Tip*: If the scale you are using does not have a feature to zero it out, you will need to first weigh the measuring boat so that you can subtract this mass from the total when you weigh the paper clips.
6. Remove all the paper clips picked up by the magnet from your magnet and gather them in your measuring boat. *Tip*: If not all the paper clips fit in your measuring boat, measure half of the clips, than measure the second half and add up the results.
7. Record the mass picked up by the magnet in your lab notebook.

Taking Measurements at Various Temperatures

Important: One more note before you start your measurements at different temperatures. Whenever you cool or heat your magnet to a desired temperature, it is very important to allow the magnet to **equilibrate** to the test temperature before measuring the magnet's strength at that temperature. Give the magnet at least 20 minutes to attain a uniform temperature when it is immersed in water and 30 minutes when it is in open air. This will ensure that not only the surface, but also the inner core of the metal, attains the desired temperature. The Introduction (#background) (see section on domains) will give you a clue on why this is so important.

Freezer Test

1. Place your magnet in the freezer for about 30 minutes.
2. Place your thermometer in the freezer.
3. Prepare your pile of paper clips as described in the section Measuring the Magnet Strength (#measuring_strength).
4. Take the magnet out, measure its strength (as described in the section Measuring the Magnet Strength (#measuring_strength)) and put it instantly back where you got it from for this test so it is ready for your next trial.
5. Leave your magnet for at least 10 minutes to equilibrate with the test temperature again.
6. Repeat steps 3–5 four more times for a total of five trials.
7. Take your thermometer out of the freezer and record the temperature of your freezer in the data table in your lab notebook. Take your magnet out of the freezer.

Ice/Water Bath Test

8. In a large plastic bowl, prepare a bath of water and ice cubes.
9. Place your magnet in the bowl. Make sure it is completely submerged.
10. Leave it in the ice/water bath for at least 20 minutes, evaluating intermittently if the bath needs extra ice. *Note*: Since the room is warmer than your ice/water bath, heat will flow from the room to the bath, melting your ice. To keep the temperature of the bath at 0°C, you might need to replenish the ice.
11. Repeat steps 3–6. While you do so, keep an eye on the ice/water bath, making sure it always contains some ice.
12. Use your thermometer to measure the temperature of the ice/water bath and record your findings in your data table. Take your magnet out of the water/ice bath.

Room-Temperature Test

13. Let your magnet and thermometer sit out at room temperature for at least 30 minutes.
14. Repeat steps 3–6. *Note*: In this case, you do *not* need the additional 10 minutes between trials, as the magnet stays at room temperature all the time.
15. Use your thermometer to measure the room temperature and record your findings in your data table in your lab notebook.

Boiling Water Test

16. Put a pot with plenty of water on the stove and bring it to a soft boil.
17. Use tongs to put the magnet in the water. You will also use the tongs to take the magnet out of the water. Leave the magnet in the water for at least 20 minutes to equilibrate.
18. Repeat steps 3–6. While you do so, keep the water at a soft boil.
19. Use your thermometer to measure the temperature of the boiling water and record your findings in your data table in your lab notebook. Take the magnet out of the water, let the water cool and safely dispose it.
20. You are finished measuring and can start analyzing your results.

Analyzing Your Data

1. For each temperature, calculate the average mass the magnet picked up. You do this by adding the masses picked up by the magnet for Trial 1, Trial 2, Trial 3, Trial 4, and Trial 5 for a given Temperature (e.g. freezer temperature) and divide this total by the number of trials, here 5. Record the average in the last line of your data table.
2. Make a graph of magnetic strength, as measured by mass picked up (y-axis, the vertical axis), vs. temperature (x-axis, the horizontal axis).
    a. *Tip:*You can make a graph by hand or make a graph using a computer program, such as Create a Graph (http://nces.ed.gov/nceskids/createagraph), and print it out.
3. Look at your data table and graph, and try to draw conclusions from your results.

a. Does magnetic strength increase, decrease, or stay the same over the temperature range you tested?
b. Can you explain these results with what you learned about ferromagnetic materials in the Introduction (#background)?
c. Could you conclude your tested magnet will still function properly under extreme kitchen temperatures? Would it be safe to extrapolate these findings to more common sizes of ceramic kitchen magnets?

Frequently Asked Questions (FAQ)

FAQ for this Project Idea available online at https://www.sciencebuddies.org/science-fair-projects/project-ideas/Phys_p025/physics/how-the-strength-of-a-magnet-varies-with-temperature#help (http://www.sciencebuddies.org/science-fair-projects/project-ideas/Phys_p025/physics/how-the-strength-of-a-magnet-varies-with-temperature#help).