

**HEAT OF
ATTRACTION:
DOES TEMPERATURE
AFFECT MAGNETIC
ATTRACTION?**



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Background

We have a lot of magnets on our refrigerator at home. These hold up school art, certificates, receipts and photos. Each magnet is often holding multiple sheets. It is common for the magnets to be at their limits of how many sheets they can hold because of how many papers are on our fridge. However, I noticed during late Summer that on a few hot days, when I got home from school, the papers and magnets were on the floor. I wondered if heat had an effect on the magnets ability to attract metal.

Introduction

From researching on the internet, there was information showing that the temperature of a magnet affected its ability to attract metals. Firstly, most home magnets are ferromagnets or ferromagnetic, which means they contain iron, cobalt or nickel. It is ferromagnetism that will be focussed on for this project. Searching websites such as “Magnum Magnetics” (<https://magnummagnetics.com/blog/temperature-effects-on-magnets/>) and “e-Magnets” (<https://e-magnetsuk.com/how-does-temperature-affect-magnets/>) described how at higher temperature the magnet’s strength gets weaker because the extra heat increases the kinetic energy of the magnet. This makes the magnet’s molecules move faster, so the molecules begin to misalign.

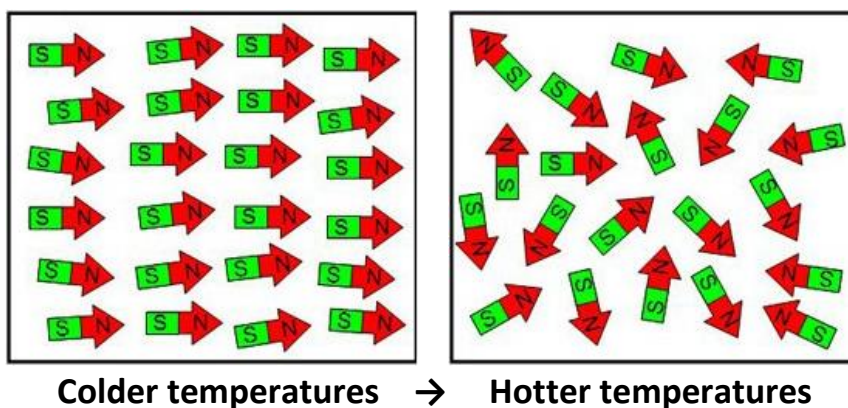


Image from Ben Finio, Science Buddies (<https://www.sciencebuddies.org/image-credit?id=6626>)

There was no clear information on the internet about how much of a difference there is at different temperatures and the level of attraction, as the websites above talked about this being a linear change, however “Magnet Expert” (<https://www.magnetexpert.com/technical-advice-for-every-application-magnet-expert-i685/temperature-effects-on-magnets-i683>) wrote about ferrite magnets becoming resistant to demagnetisation as the temperature gets higher.

A magnet attracting a metal can be looked at in two different ways, the distance to attract an object and the number of objects it can attract. Both are intended to be examined in this project.

Aim

The aim of this experiment was to determine if there was a difference in a magnet’s ability to attract metal paper clips due to the temperature of the magnet.

Hypothesis

The hypothesis for this experiment was that the lower the temperature of the magnet the more the magnet can attract metal. Therefore, the lower the temperature the greater the mass of paperclips that could be attracted to the magnet and the longer the distance the magnet could be from a paperclip before attracting it. The hotter magnets would attract a lower mass of paperclips and would need to be closer to the paperclip before attracting the paperclip.

Variables

Dependant variable: Magnetic attraction (distance or mass of attraction).

Independent variable: The different temperatures of the magnet (-20°C, 0°C, 20°C, 40°C, 60°C, 80°C and 100°C)

Controlled Variables: This experiment used the same measuring devices (scales, thermometers and ruler) and the same magnet and paper clips (including the same orientation of the magnet and paper clip for distance).

The magnet was placed at the temperature for exactly 20 minutes and in the same way to ensure all treatment was equal and did not differ between groups. The magnet was applied in the same way for each attempt to ensure consistency in approach.

Materials

Here is a list of all the materials used in this experiment. The brackets note the product used in this experiment; however, this could be modified.

- Bar magnet (Everhang 10x48 Ceramic Rectangle Magnet)
- 250 Metal Paperclips (Anko 28mm paperclip)
- Thermometer (Brunnings Wall Thermometer)
- Kitchen thermometer (Fildes Food Safety Coffee Thermometer)
- Kitchen Scales (Salter Digital Kitchen scales)
- Ruler (Flexi Clear Plastic Ruler)
- Pencil (Staedtler HB)
- Paper (Spirax A3 Sketchbook)
- Large mixing bowl (VISPAD mixing bowl, white)
- Water (Filtered Tap Water)
- Kettle (Breville Soft Top Dual)
- Kitchen Tongs (steel and silicone – Anko 30cm Heavy duty Tongs)
- A Phone (Samsung Galaxy A11 phone)
- A Computer (DELL laptop) with internet access



Methods

Here are the steps undertaken to complete this experiment. This experiment required the completion of a Risk Assessment. Please read this before starting (see Risk Assessment Form at the end of this report in the Appendix).

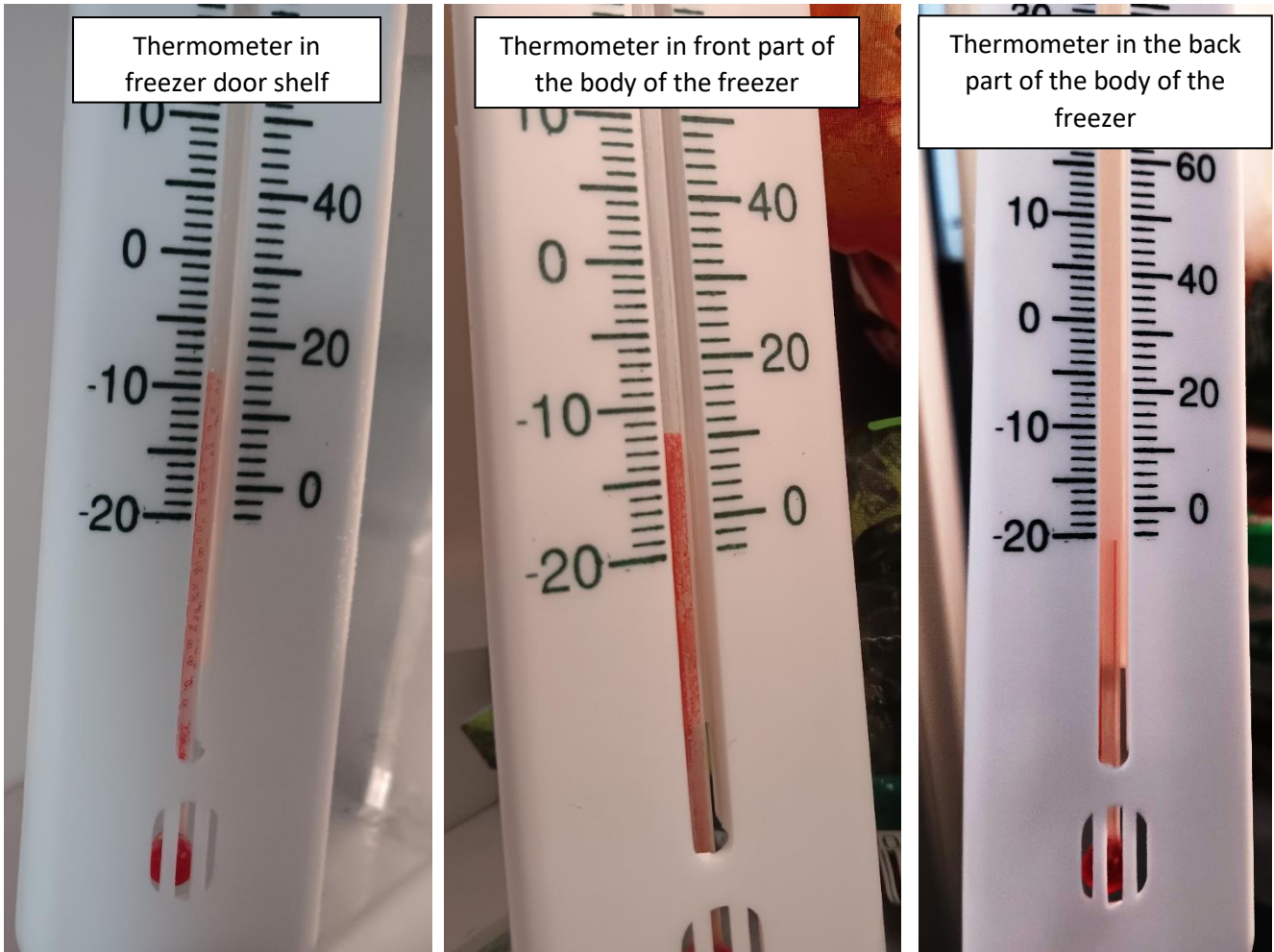
Step 1: Purchase all the items that you need for the experiment.

Step 2: Label the magnet with the pencil with a cross on the side of the magnet to be pointing away from the paper clips. Draw a straight line on the paper towards one end (like a margin) and place the paperclip against the line (inside the margin) with a ruler aligned to 0cm on the pencil line (see first photo below). Place all the other paperclips into a neat pile on a table with the kitchen scales next to them (see second photo below).



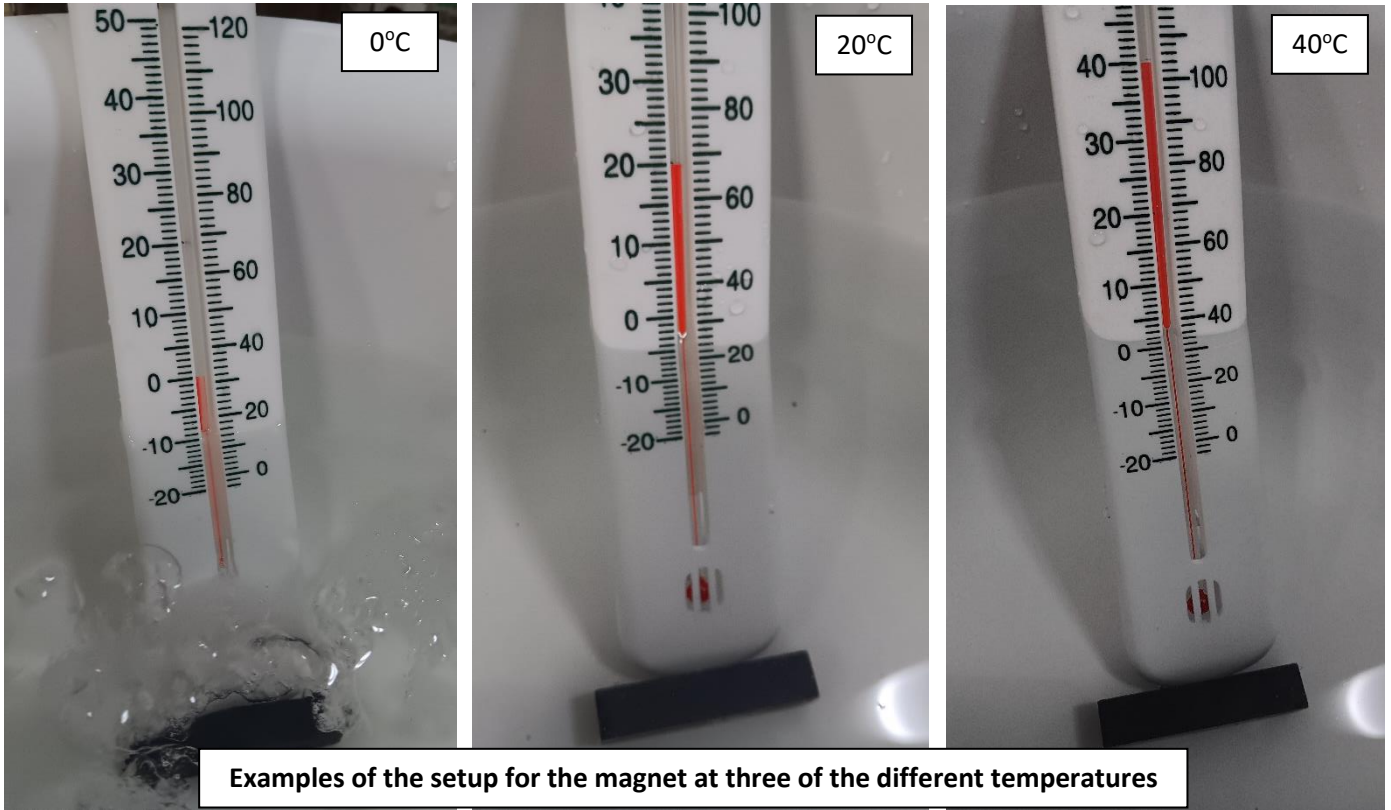
Step 3: The magnet should face upwards (marking on top) for this step, when the magnet is brought to the required temperature. Use the phone to time the 20 minutes and to take photos.

- For the -20°C , place the thermometer into the freezer (set at -20°C) and leave for 20 minutes. Check the thermometer after 20 minutes and if it has not reached -20°C move to another part of the freezer (the door shelves are the warmest and back of the freezer is coolest – see photos below). Check again after another 20 minutes. When you find a spot where the thermometer reads -20°C , place the magnet in the freezer with the thermometer for 20 minutes. Use the tongs for the thermometer and to pick up (from above) the magnet.



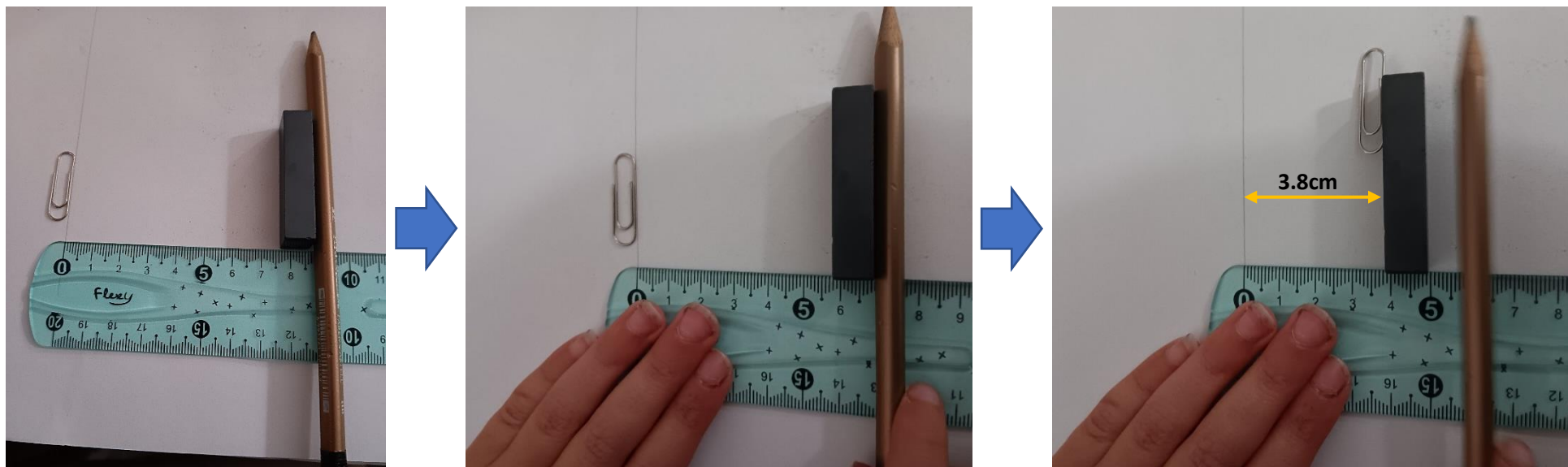
- For the 0°C , place the thermometer in an ice bath and adjust with more ice or water to bring the thermometer to 0°C . Place the magnet in and monitor the temperature. You need to add more ice or water if the temperature gets hotter or cooler. After 20 minutes remove the magnet from above with the tongs for the experiment.
- For the 20°C , 40°C , 60°C and 80°C , take decreasing amounts of room temperature water and carefully add boiling water from the kettle. For the 20°C and 40°C temperatures, place the wall thermometer into the water. For the 60°C and 80°C temperatures add the kitchen thermometer into the water and adjust the amount of cold or hot water to bring it to the right temperature. Once at temperature, add the magnet for 20 minutes. Continue to add more boiling or ice water throughout the 20 minutes to ensure the thermometer stays at temperature. Remove the magnet with the tongs (from above) at the end of the 20 minutes.

- For the 100°C, carefully only add boiling water to the bowl. Place the kitchen thermometer into the bowl and the magnet. Continue to add more boiling water throughout the 20 minutes to ensure the thermometer stays at 100°C. Remove the magnet with tongs from above.



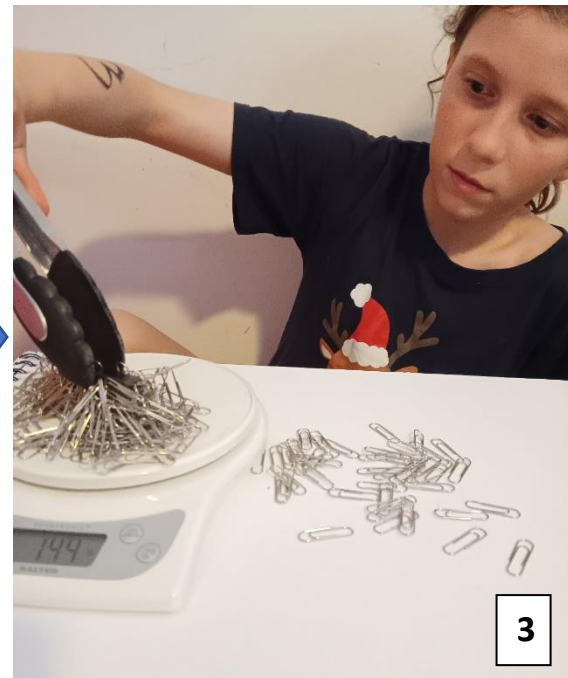
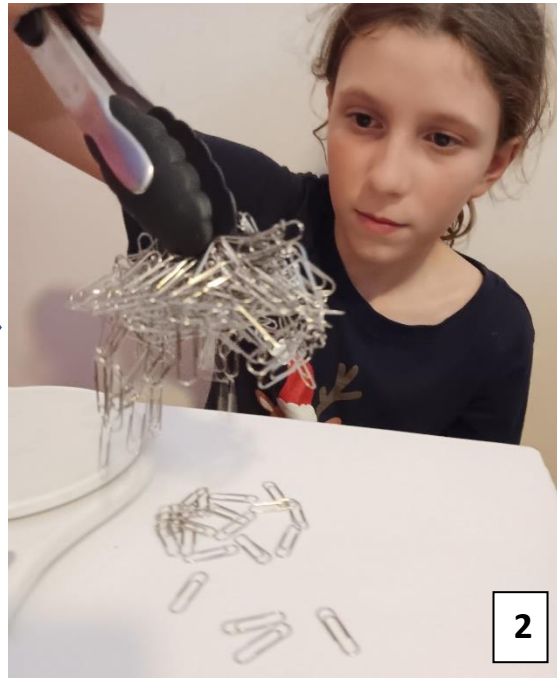
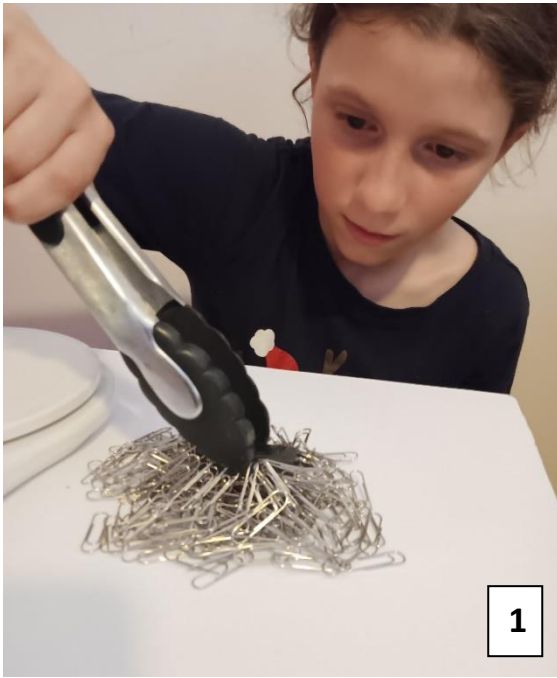
Step 4: When you have removed the magnet with tongs very quickly approach the prepared experiment space for one of the following options. Use the magnet for one or other of the following two experiments but not both as the temperature will have changed too much. Each of these two experiments needs to be repeated at least 10 times for each temperature.

- **Option 1:** Place the magnet onto the paper, orientating it quickly using the mark so it stays in the same place each time. Make sure the magnet is parallel to the paperclip but about 8-10cm away. Use the side of a pencil to slowly push the magnet towards the paperclip, use an aligned ruler to keep the magnet parallel. When the magnet attracts the paperclip, move the pencil backwards quickly to stop pushing and note down the distance from the magnet to the pencil line. See photos below for set up and step-by-step for how the experiment works.



Photos showing steps for option 1.

- **Option 2:** Using the tongs place the magnet onto the top of the pile of paperclips. Pick the magnet up with the paperclips hanging from the magnet. Place the magnet onto the scales. Clear away all the paperclips that were not lifted by the magnet. When the magnet is closer to room temperature (warmed up or down enough to touch), pull the paperclips off the magnet and place them onto the scales to weigh them. Don't include the magnet. Note down the mass of the paperclips. See photos on the next page for a step-by-step guide for how the experiment works.



Photos showing steps for option 2.



Step 5: Go back to Step 3 to repeat this 140 times (ten times for each of the two options for every one of the seven temperatures), however you may need to wait for the water to have warmed up or cooled down sufficiently to tip it out for the next round. Make sure you write down and photograph your findings for each repeat step.



Sample of some of the measurements. These were the first three weights for -20°C.

Step 6: Analyse the results. Enter the results into Microsoft Excel, and calculate the mean and standard deviation for each group in Microsoft Excel. Use SPSS Statistics 27 software to calculate if there is a statistically significant difference between the temperature groups. As there is only one independent variable (different temperatures) and there is not a control group this data could be analysed using a Repeated Measures ANOVA (<https://statistics.laerd.com/spss-tutorials/one-way-anova-repeated-measures-using-spss-statistics.php>) and the step-by-step guide is available at: <https://statistics.laerd.com/spss-tutorials/one-way-anova-repeated-measures-using-spss-statistics-2.php>. Statistical significance was reached if $p < 0.05$.

Results

The following tables and graph show the results for this experiment. Table 1 and the middle column of Table 3 show that there was a decrease in the distance that the magnet was able to attract the paperclip as the magnet got hotter. This ranged from an average distance of 56mm (at -20°C) to 38mm (at 100 °C). This is a reduction of approximately one third of the attraction distance due to the 120°C temperature increase. Table 1 also shows the consistency between samples and this is calculated with the standard deviation in Table 3.

Table 2 and the last column of Table 3 show that there was a decrease in the mass that the magnet was able to attract the paperclip as the magnet got hotter. This ranged from an average mass of 56.2g (at -20°C) to 37.3g (at 100 °C). This is a reduction of approximately one third of the mass of paperclips attracted due to the 120°C temperature increase. Table 2 also shows the consistency between samples and this is calculated with the standard deviation in Table 3.

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean magnetic attraction differed statistically significantly between the different temperatures in the maximum distance it could attract a paperclip ($F(3.728, 33.556) = 140.303, p < 0.001$). Post hoc analysis with a Bonferroni

adjustment revealed that difference in the distance of paperclips magnetically attracted was statistically significant and the distance decreased from -20°C (longest distance) compared to all hotter temperatures up to 100°C (shortest distance) (p value ranged from p=0.039 to p<0.0001).

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean magnetic attraction differed statistically significantly between the different temperatures in the mass of paperclips it could attract ($F(3.795, 34.151) = 85.809, p < 0.001$). Post hoc analysis with a Bonferroni adjustment revealed that difference in the mass of paperclips magnetically attracted was statistically significant and the mass decreased from -20°C (highest mass) compared to all hotter temperatures up to 100°C (lowest mass) (p value ranged from p=0.041 to p<0.0001).

Table 1: Table showing the distances that the magnet could attract a paperclip (rounded to the nearest mm) for the magnet at each temperature.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
-20°C	58mm	57mm	53mm	59mm	56mm	54mm	55mm	57mm	56mm	55mm
0°C	55mm	51mm	52mm	51mm	54mm	51mm	54mm	50mm	54mm	53mm
20°C	50mm	47mm	49mm	48mm	51mm	48mm	52mm	49mm	46mm	50mm
40°C	49mm	44mm	44mm	46mm	45mm	47mm	47mm	48mm	44mm	46mm
60°C	45mm	41mm	42mm	41mm	43mm	44mm	45mm	41mm	46mm	42mm
80°C	39mm	42mm	39mm	38mm	43mm	40mm	41mm	38mm	43mm	42mm
100°C	38mm	36mm	39mm	40mm	41mm	38mm	36mm	38mm	37mm	37mm

Table 2: Table showing the mass of the paperclips that the magnet could attract for each temperature.

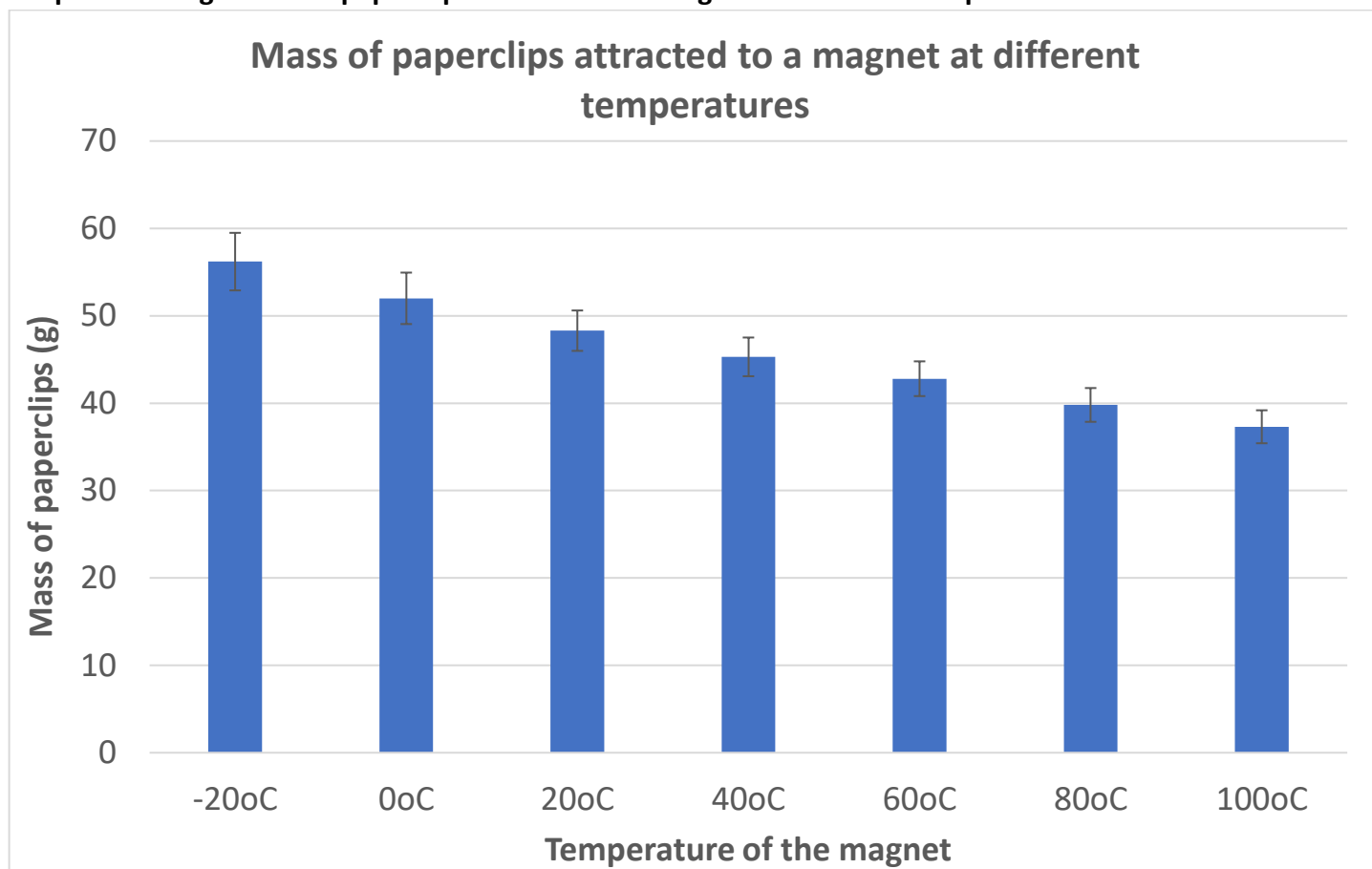
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
-20°C	55g	61g	54g	53g	58g	56g	59g	50g	59g	57g
0°C	48g	47g	55g	52g	49g	53g	54g	55g	53g	54g
20°C	46g	49g	46g	50g	48g	49g	45g	47g	51g	52g
40°C	44g	42g	47g	48g	43g	48g	47g	43g	46g	45g
60°C	43g	41g	46g	43g	44g	42g	39g	42g	43g	45g
80°C	42g	38g	42g	37g	41g	40g	41g	41g	39g	37g
100°C	40g	35g	36g	38g	37g	39g	35g	37g	36g	40g

Table 3: Table showing the average results for each temperature.

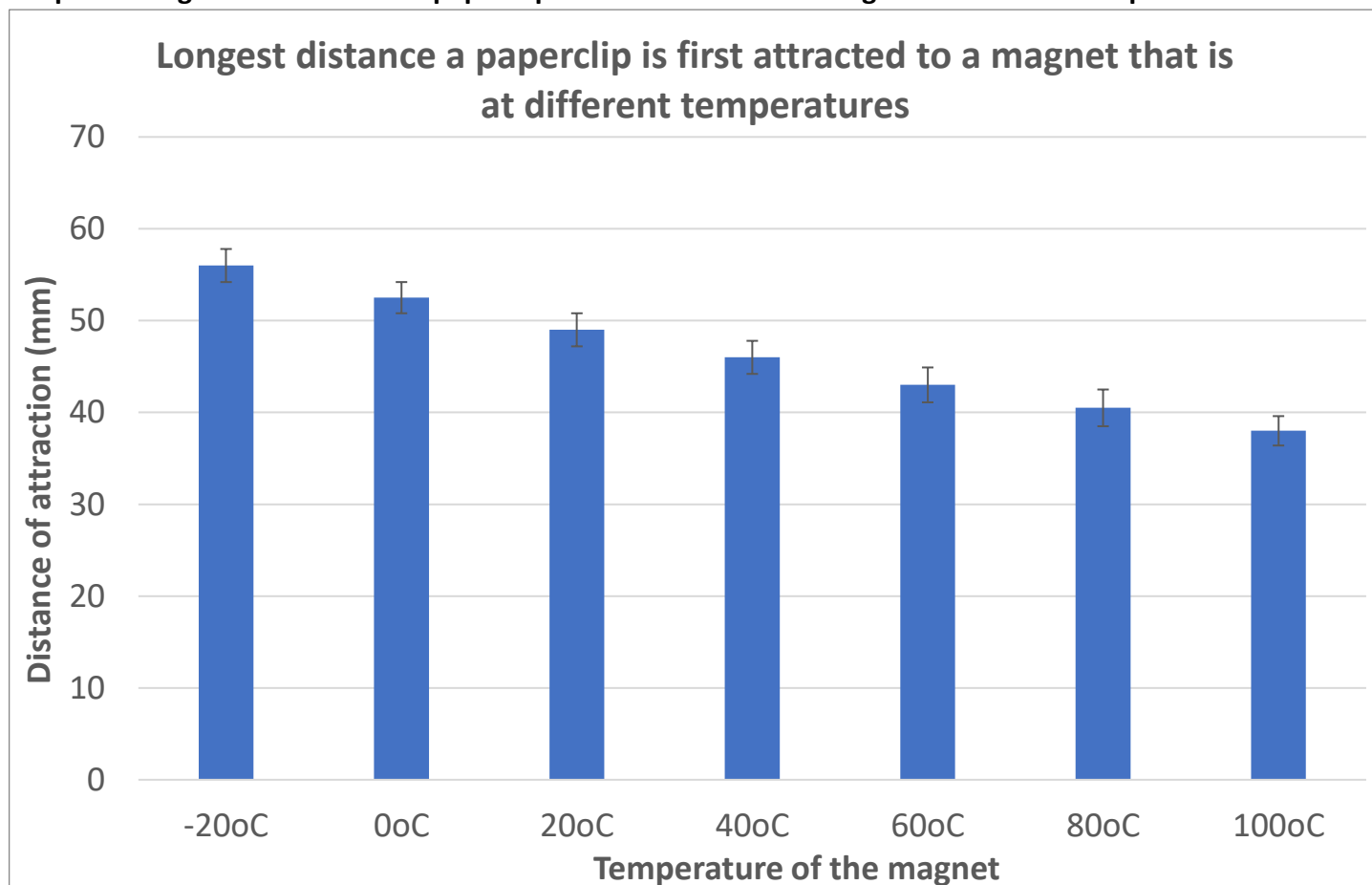
	Distance of paperclip attraction (mean ± standard deviation)	Mass of paperclips attracted (mean ± standard deviation)
-20°C	56.0mm ± 1.8mm	56.2g ± 3.3g
0°C	52.5mm ± 1.7mm	52.0g ± 2.9g
20°C	49.0mm ± 1.8mm	48.3g ± 2.3g
40°C	46.0mm ± 1.8mm	45.3g ± 2.2g
60°C	43.0mm ± 1.9mm	42.8g ± 2.0g
80°C	40.5mm ± 2.0mm	39.8g ± 1.9g
100°C	38.0mm ± 1.6mm	37.3g ± 1.9g

The data from Table 3 was displayed in graphs (Graph 1 and Graph 2) to visualise the differences between temperatures.

Graph 1: Average mass of paperclips attracted to a magnet of different temperatures



Graph 2: Longest distance that a paperclip is first attracted to a magnet of different temperatures



Discussion

This experiment showed that the magnetic attraction decreased as the temperature of the magnet increased. This inverse relationship was statistically significant for both the maximum distance of attraction and the mass of objects that the magnet could attract. This result supported the hypothesis. The decrease was approximately one third of the attraction of the magnet across the temperatures tested. This experiment did show that magnets could still work at higher temperatures, but worked best at lower temperatures. This is supported by what was seen from the internet research.

Application of results

As magnets are used in many motors, electricity generation and engineering projects, it would be important to consider the temperature when calculating where the magnet will be used. A one-third reduction in magnetic attraction would be important considerations depending on whether you are in an Antarctic winter compared to hot desert conditions. This would also be important for space travel, where every gram reduction is critical, however the temperatures in space can be very low. Finally, with global warming and climate change increasing temperatures across the world, this could have additive issues with even minor reductions in magnetic attraction.

Limitation

There were a few limitations with this research. Firstly, there were only two methods of magnetic attraction tested. It might be possible that other application methods might have other results. Also, the ruler and kitchen scales didn't accurately measure micrometres or micrograms. Therefore, this may have improved the accuracy of measurements.

This project only focussed on ferromagnets and other types of magnets may have had different results.

Future Research

In the future, this experiment could be built on by trying:

- Different ferrous magnets (different shapes and sizes).
- Different types of non-ferrous magnets
- Different metallic objects (use items other than paperclips).

All of these options could be useful especially when considering the wide-reaching applications, such as engineering or space travel. This would be especially important for creating structures to inhabit on other planets.

Conclusion

This experiment has answered the aim and has shown that the magnetic attraction decreased as the temperature of the magnet increased. The decrease in magnetic attraction was approximately one third over the temperature range (-20°C to 100°C). Hopefully, knowing this information will help with better planning for engineering and electrical projects, especially when you factor in global warming.

Acknowledgements

I would like to acknowledge my parents who took me to the shops to purchase all the materials. They also let me use their phone and computer, and helped me when the tables needed formatting and I wanted to add the error bars to the graph. My mother also helped showing me the statistics software and the guide on how to use it. I want to thank my brother and sister for leaving me alone so I could get this work done in quiet. The computer was also very helpful, as the spelling and grammar checker fixed all my mistakes.

References

- Magnum Magnetics: <https://magnummagnetics.com/blog/temperature-effects-on-magnets/> (Accessed 26 March 2024)
- e-Magnets: <https://e-magnetsuk.com/how-does-temperature-affect-magnets/> (Accessed 26 March 2024)
- Science Buddies: <https://www.sciencebuddies.org/image-credit?id=6626> (Accessed 27 March 2024)
- Magnet Expert: <https://www.magnetexpert.com/technical-advice-for-every-application-magnet-expert-i685/temperature-effects-on-magnets-i683> (Accessed 27 March 2024)
- Laerd Statistics: <https://statistics.laerd.com/spss-tutorials/one-way-anova-repeated-measures-using-spss-statistics.php> and <https://statistics.laerd.com/spss-tutorials/one-way-anova-repeated-measures-using-spss-statistics-2.php> (Accessed 29 April 2024)
- Risk Assessment Form www.riskassess.com.au (Accessed 26 March 2024)

Appendix

Risk Assessment Form



Risk Assessment Form:

Name of Entry Heat of Attraction: Does Temperature affect magnetic attraction?

Student Name: Charlotte D'Amore Signature: _____ Date: 4 May 2024

Student Name: _____ Signature: _____ Date: _____

Your assessment should include sample handling, storage, disposal, spill procedures and use of machinery...

Use as many pages as necessary, a blank table provided on the next page.

Type of Risk	Hazard	Level of Risk	Precaution taken to control risk	Source of information
<input type="checkbox"/> Chemical or microorganism <input checked="" type="checkbox"/> Procedure or equipment	Burns due to hot water.	Low	Conduct the experiment with care. Use the kettle carefully and ask an adult to help hold the bowl so nothing can tip out. Use tongs to pick up the magnet and allow the magnet and water to cool before touching it.	www.riskassess.com
<input type="checkbox"/> Chemical or microorganism <input checked="" type="checkbox"/> Procedure or equipment	Freezer burns	Low	Conduct the experiment with care. Avoid contact with the freezer and use tongs to touch the thermometer and magnet.	www.riskassess.com
<input type="checkbox"/> Chemical or microorganism <input type="checkbox"/> Procedure or equipment				
<input type="checkbox"/> Chemical or microorganism <input type="checkbox"/> Procedure or equipment				

Possible sources of information to complete your risk assessment

- www.riskassess.com.au
- Search: safety data sheet