EFFECT OF TEMPERATURE ON THE STRENGTH OF MAGNET

Abstract

The magnetic field will attract ferrous materials like iron or nickel. It also attracts or repels other magnets depending, on the polarity of the other magnets Permanent magnets are made from materials that will remain magnetized and are hence able to maintain the magnetic field around them continuously. An example is the small magnets used to hold notes on refrigerator doors.Permanent loss of magnetic performance is experienced when a magnet is heated above its Curie temperature. At this point the structure of the magnetic domains change and become self-kippering, resulting in permanent magnetic damage which cannot be repaired by remagnetisation.Magnetic materials should maintain a balance between temperature and magnetic domains (the atoms'inclination to spin in a certain direction). When exposed to extreme temperatures, however, this destabilized, magnetic properties are then affected, while cold strength magnet, heat can result in the loss of magnetic properties.

Keywords: magnetic domains, cold strength magnet, Curie point, magnetic poles

1. INTRODUCTION

The first known magnets were naturally occurring lodestones, a type of iron ore called magnetite (Fe3O4). People of ancient Greece and China discovered that a lodestone would always alignitself in a longitudinal direction if it was allowed to rotate freely. This property of lodestones allowed for the creation of compasses two thousand years ago, which was the first known use of the magnet in 1263 Pierre de Mari court mapped the magnetic field of a lodestone with a compass. He discovered that a magnet had two magnetic poles North and South poles. In the 1600's William Gilbert, physician of Queen Elizabeth I, concluded that Earth itself is a giant magnet. In 1820 the Danish physicist Hans Christian Rested, discovered an electric current flowing through a wire can cause a compass needle to deflect, showing that magnetism and electricity were related. In 1830. Loomis 2023 wrote about the effects of the changes of temperature on permanent magnets on heating and cooling.

Michael Faraday (British) and Joseph Henry (American) independently discovered that a changing magnetic field produced a current in a coil of wire. Faraday, who was perhaps the greatest experimentalist of all time, came up with the idea of electric and magnetic “fields.” He also invented the dynamo (a generator), made major contributions to chemistry and invented one of the first electric motors. In the 19th century James Clerk Maxwell, a Scottish physicist and one of the great theoreticians of all times, mathematically unified the electric and magnetic forces. He also proposed that light was electromagnetic radiation. In the late 19th century Pierre Curie discovered that magnets loose their magnetism above a certain temperature that later became known as the Curie point. A magnet is an object that will produce a magnetic field around it also magnet can be defined as any object that produce magnetic field, some magnets referred to as permanent, hold their magnetism without an external electric current, a magnet of this nature can be created by exposing a piece of metal containing iron to a number of situation, soft magnet on the other hand, are those that lose their magnetic charge properties over time. Additionally paramagnetic objects are those that can become magnetic only when in the presence of an external magnetic field, a magnetic field is a space surrounding a magnet in which magnetic force is exerted, the motion of negatively charged electrons in the magnet determines not only the polarity but also the strength of the magnet. Because of capability of a magnet, magnetism has been a big part in development of machines and gadgets that are of great use in the modern age. In this study we are able to investigate on the factors that affect the magnetic strength particularly the temperature. Furthermore the magnetic field will attract ferrous materials like iron or nickel. It also attracts orrepels other magnets depending, on the polarity of the other magnets Permanent magnets are made from materials that will remain magnetized and are hence able to maintain the magnetic field around them continuously. An example is the small magnets used to hold notes on refrigerator doors. Ferromagnetic materials like iron, cobalt and nickel have a very strong attraction towards magnets. Some ferromagnetic materials will become magnetic when exposed to a magnetic field for a long time. They will be able to retain the magnetic properties even after the field is removed. Other "soft" ferromagnetic materials will lose their magnetism once the magnetic field disappears when an electric current flows through a coiled wire, an electromagnet will be produced. However, when the current is removed, the magnetic properties will be lost. By placing ferromagnetic materials in the middle of the coil, the magnetic strength of the coil will be increased many times over also temperature are the degree of hotness or coldness of the body or substances.

There are three types of performance loss experienced by magnets when exposed to elevated temperatures.

REVERSIBLE LOSS

Reversible loss occurs for every degree rise in temperature the magnet experiences above ambient, up to its maximum operating temperature. As the magnet cools, the performance returns to the previous level

IRREVERSIBLE LOSS

When a magnet is heated above its maximum operating temperature but below its Curie temperature, it will experience irreversible losses in performance. This means if the magnet is then cooled, its performance will be weaker than it was before it was heated. A magnet that has experienced irreversible loss could theoretically be remagnetised back to its original strength, but this is not a cost effective process. Irreversible loss is a result of the elevated temperature reversing the magnetization of single individual magnetic domains. This means that irreversible loss happens just once; if the same thermal cycle is repeated no additional loss will occur as each individual domain can only be reversed once after it is magnetised.

PERMANENT LOSS

Permanent loss of magnetic performance is experienced when a magnet is heated above its Curie temperature. At this point the structure of the magnetic domains change and become self-kippering, resulting in permanent magnetic damage which cannot be repaired by remagnetisation.

The Curie temperature of permanent magnetic materials is often quoted on datasheets, but when taken in isolation this is often the least useful thermal characteristic when designing an application as no design should function close to these extreme high temperatures. Therefore, other parameters such as maximum operating temperature should be considered

Curie temperature

Each ferromagnetic material has a Curie temperature, above which it can no longer be magnetized. For example, iron has a Curie temperature of over 1,300°C.

A higher temperature weakens a magnet's strength and magnetic field. As heat increases the magnet's kinetic energy and makes its molecules move faster, they become more and more sporadic.

The objectives of this project is to determine whether the temperature of the magnet affects its strength. Also we want to see if we change the temperature of a magnet it works better or worst.

Specificallytest will be done on magnets at different temperatures to see if their strength is affected. The purpose of this project is to determine how extreme temperature affects magnets. For the given permanent magnet we would like to calculate the different distances of sensitivity of the needle of the compass when magnet is subjected approaching to the compass by using a metre rule

It is hypothesized that Increasing the temperature of a magnet reduces its strength. If a magnet is exposed to different temperatures it would work better in cold temperatures than at hot or room temperatures. A magnet in cold temperatures would carry or attract more, so when a magnet is on cold temperatures has more attraction than when they are on hot temperatures.

The studies are; significant as itfurther elaborate on how a magnetic strength changes accordance to a certain temperature and why that kind of reaction happens.It enable us to develop and improve the machines and devices that are already using magnets as one of its main components.It enable us to look further on the possible advantages and flaws on the concept of magnetism.It allow us to abroad the use of this material.It paves the way for us to increase its efficiency.

2. LITERATURE REVIEW

The amplitude of the external magnetic field and the ambient temperature are important factors to determine the magnetic properties of permanent magnets after magnetization. In this paper, the magnetic properties of NbFeB (N50) permanent magnets in 60-300K are measured by a physical property measurement system (PPMS) in the quasi-static magnetic field, and the minimum magnetic field required for saturation magnetization of NbFeB permanent magnet decreases gradually with the increase of temperature. In addition, the effect of eddy current on the magnetic field and temperature of permanent magnet during pulse magnetization are also studied by the comparison of pulse magnetization experiments (Tu et al.2021.)

Temperature cycling tests in various temperature ranges were carried out to investigate the magnetic degradation of the Zn-coated NdFeB magnet. The losses of the surface magnetic field and magnetic flux were well fitted by using an index model. Compared with the lower limit temperature, the upper limit temperature had more obvious effect on the magnetic degradation. Once the upper limit temperature exceeded ≥160 °C, the magnetic degradation mainly occurred during the first cycle, which was different from the gradual decline with an increase in cycle number at a temperature of ≤140 °C. Moreover, the temperature cycling with a maximum upper limit temperature of 180 °C led to a loss of the remanence intensity, while the coercivity remained stable. Microstructure and element distribution analysis revealed that the oxidation of the Zn coating layer during the temperature cycling causes its cracking and an insertion of the oxygen element into the NdFeB substrate. The Nd-, Pr-rich phase at grain boundaries provided diffusion channels for oxygen elements, leading to a surface oxidation of NdFeB grains. (Wu et al.2022).

Microstructures of $Sm(Co_{bal}Fe_{0.12}Cu_{0.07}Zr_{0.02})_7$ high temperature magnets with different final slow cooling aging temperatures were investigated to uncover the underlying mechanism of magnetic property losses after operating at 500 °C. When the final slow cooling aging temperature is 400 °C, lower than the operating temperature, both remanence and coercivity reduce after operating, and cannot be recovered to the initial state. Such losses stem from the secondary diffusion induced microchemistry change in the high temperature environment, which will seriously shorten its service life. While when the final slow cooling aging temperature is 500 °C or higher than the operating temperature, the remanence slightly reduces but the coercivity remains nearly unchanged after operating, and can be recovered to the initial level. Consequently, our comparative investigations suggest that final aging at temperatures equivalent or higher than the operating temperature can not only provide stable and reliable magnetic properties for application, but also extend the service life of the present Sm-Co-based magnets.(Xia et.al.2021)

This science project was conducted to determine how extreme temperature affects magnets. For the givenpermanent they have obtained, they would like to calculate not only the Curie point but also the slope of decrease of magnetism that occurs as they said to a curie point is approached. Also they believe that the colder the magnet the stronger the magnet force, graphically they are results will resemble an exponential curve, with magnetic force decreasing at temperature increases. They are independent variable is temperature and dependent variable is magnetism; this will be calculated using the amount of bb pellets that the magnet is able to collect at each measured temperature also they have used the following supplies, Bowl, 1,000 BB's, scale, magnet, oven, freezer, freezer thermometer. On their experiment the following procedures were used;

Cold Process

1. Place BB's in bowl.

2. Situate scale near bowl.

3. Weigh magnet and record.

4. Place magnet and freezer thermometer in freezer set to lowest temperature possible.

5. Wait approximately 20 minutes for the magnet to reach the temperature of the freezer.

6. Record temperature read by freezer thermometer.

7. Place a magnet in the bowl filled with BB's

8. Remove magnet and attached BB's and place on a scale.

9. Record temperature of a magnet and gram attracted.

10. Subtract the weight of magnet from the weight of the magnet and the BB's combined.

11. Remove BB's and place back in the bowl.

12. Set the freezer to 5-celsius degrees high than previous temperature.

13. Repeat steps 4-12 until freezer and magnet have reached zero degree Celsius.

Hot Process

1. Place BB's in the bowl.

2. Situate scale near the bowl.

3. Weigh magnet and record.

4. Place magnet in oven set to highest temperature possible.

5. Wait approximately 20 minutes for the magnet to reach the temperature of the oven.

6. Place a magnet in the bowl filled with BB's.

7. Remove magnet and attached BB's and place on a scale.

8. Record temperature of a magnet and gram attracted.

9. Subtract the weight of magnet from the weight of the magnet and the BB's combined.

10. Remove BB's and place back in the bowl.

11. Allow magnet toreset for 5 minutes undisturbed.

12. Repeat steps 6-11 until the magnet reaches the room temperature

Their data was been recorded on the table as following;

Table 1 :Magnet strength with colder temperature

Temperature(degrees celcius)				Weight attached(+/-2.5 grames		
-21.3				275		
-19.4				275		
-18.1				265		
-15.3				270		
-13.7				260		
-6.7				245		
-4.6				220		
-1.7				200		
0				225		

Its graph

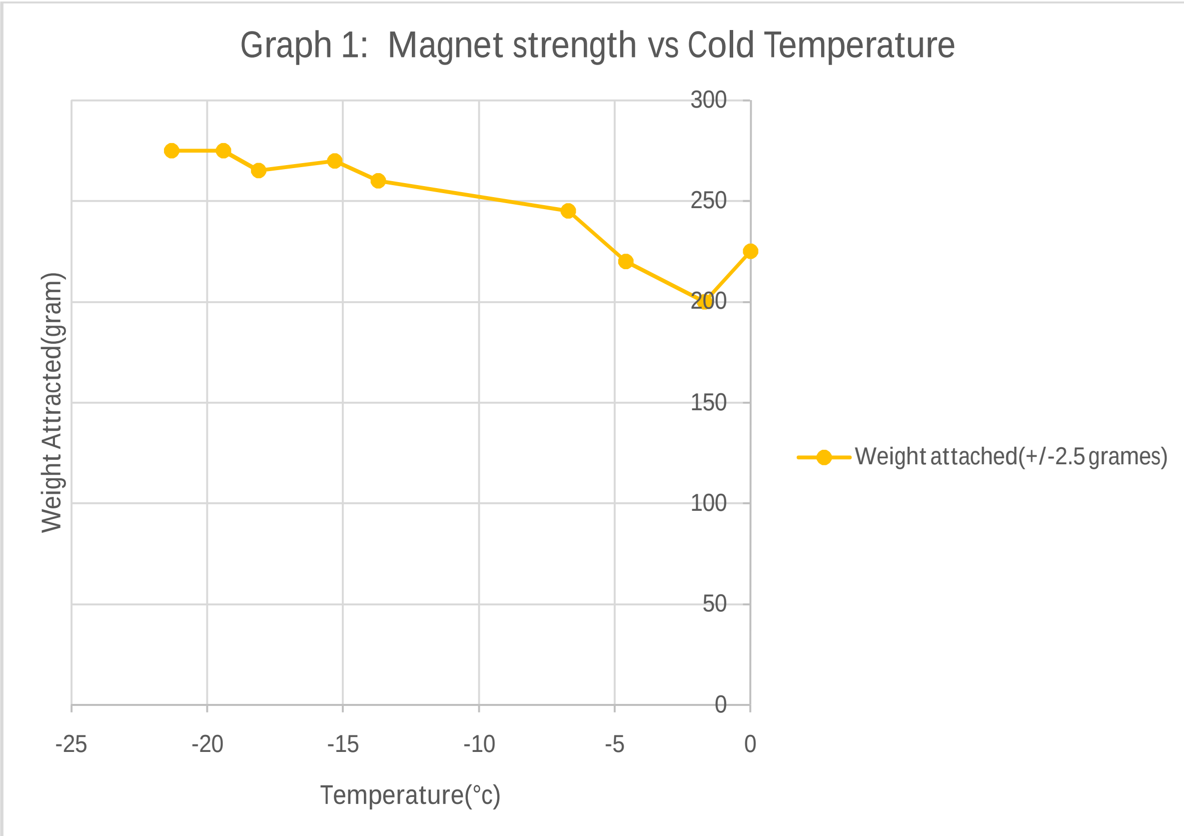
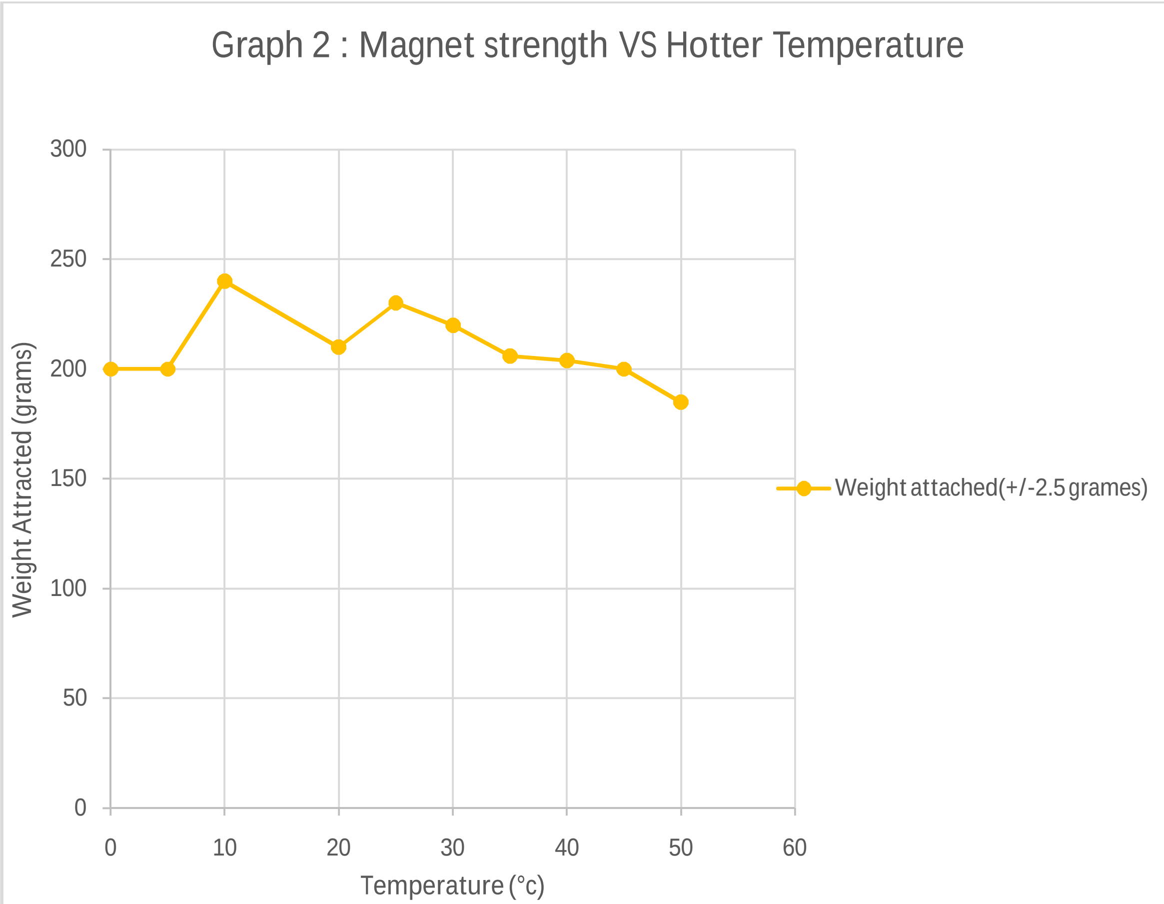


Table 2 :Magnet strength with Hotter Temperature table of results

Temperature(degrees celcius)	Weight attached(+/-2.5 grames
0	200
5	200
10	240
20	210
25	230
30	220
35	206
40	204
45	200
50	185

Its graph



But for our project we want to determine the how the temperature affect the strength of magnets by subjecting the bar magnet in different temperature such as 25°c,30°c,50°

C,70°c.90°c and 98°c also by using a metre rule can measures the angle of deflection of a compass when a bar magnet is sliding on a ruler to approach the compass as shown in the procedures session.

Observations on the effect of temperature on the strength of magnets were made. Does the temperature of a magnet affect its strength and specifically aims to give information on

i. What are the effects of the temperature to the rate of the pull of a magnet?

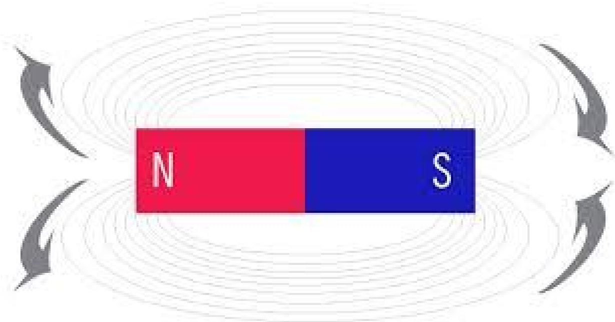
ii. How are the temperatures related to the magnetic strength?

3. MATERIALS AND METHODOLOGY

3.1 The procedures carried out the experiment

The following procedures and methods was carried out through

1. Set one magnet out on a table so that it reaches room temperature, as shown below



2. Place another magnet in a pot of boiling water for 45 seconds as shown below

3. Place the compass on a flat table so that the needle facing right

Figure 1: The compass

4. Turn the compass so the needle lines up with the ‘0.’ Tape the compass to the table.
5. Tape the ruler to the table so that its direction is perpendicular to that of the needle. The ‘0’ on the ruler should touch the ‘0’ on the compass.
6. Take a magnet (using tongs for the heated and cooled magnets) and slide it along the ruler towards the compass. You want the needle to move towards the magnet, so if it is moving away, flip it over.

Figure 2.(a) A ruler with a bar magnet

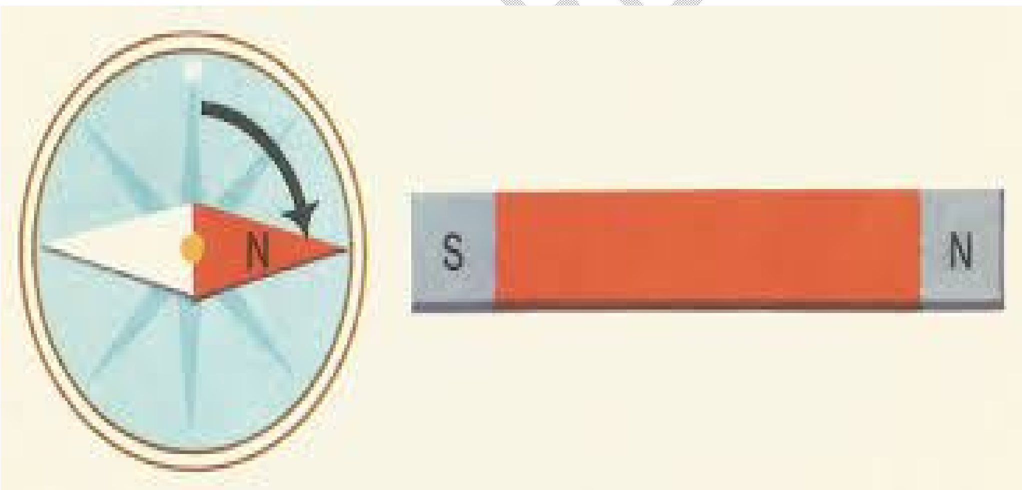


Figure2.(b) Sensitivity of compass needle near the bar magnet

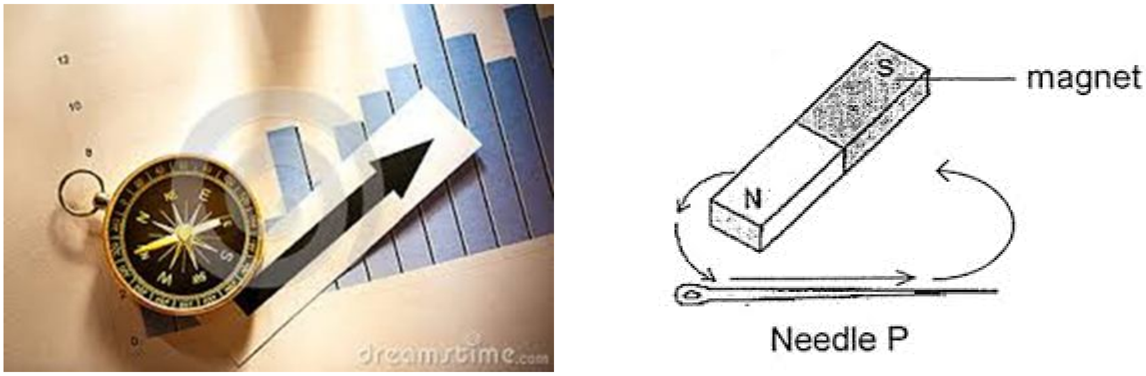


Figure 2 (c) Action of sensitivity of a compass to the bar magnet

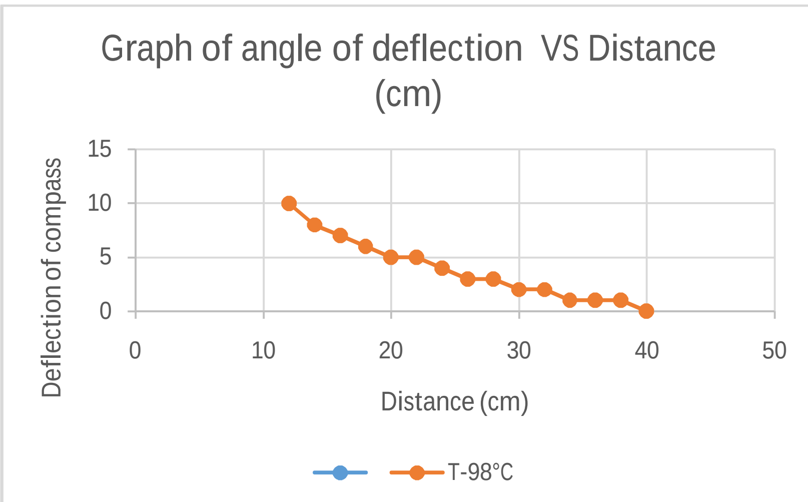
Other instrument (materials) used in this experiment which are tongs, thermometer and ruler as shown below

figure 3. Other different materials used

7. Take note of the distance between the magnet and the compass when the needle of the compass begins to move. Compare the distances you recorded for all of your magnets.

8. Repeat procedure 3,6 and 7 for different temperatures such as 25 celcius degree,30 celcius degree 50 celcius degree 70 celcius degree,90 celcius degree and 98 celciusdegree ,thefollowing results were obtained.

4. Results and Discussions



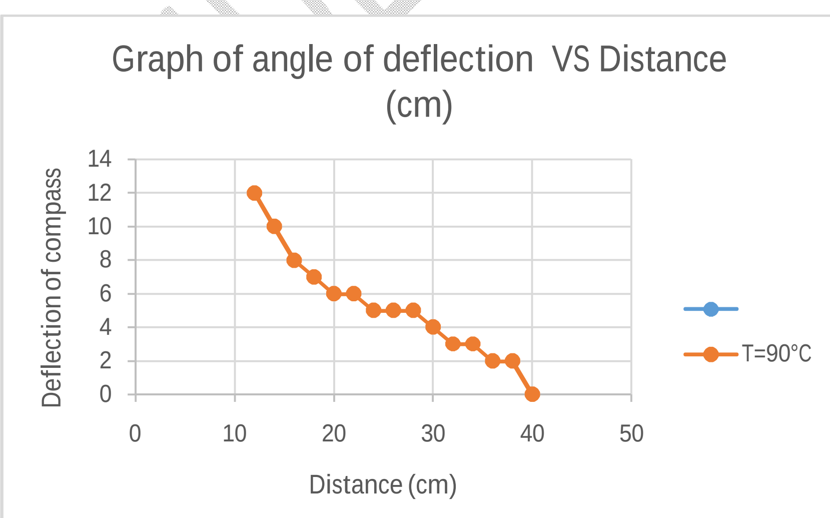


Fig 4. Results for the bar magnet at Temperature 90 degreecelcius

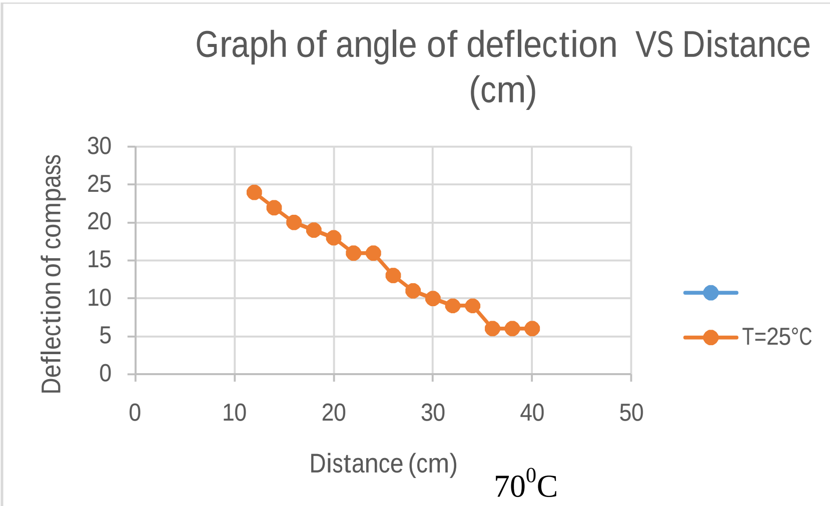


Fig 5. Results for the bar magnet at Temperature 70 degreecelcius

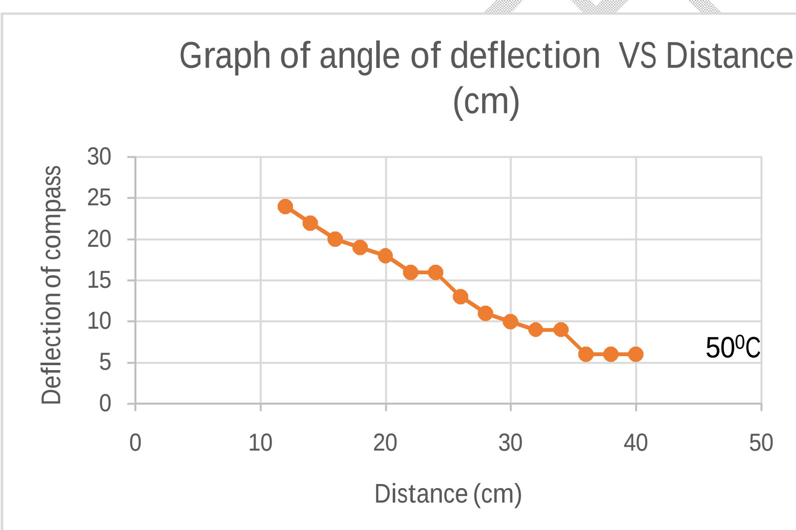


Fig.6 of results for the bar magnet at temperature of 50 degreecelcius

Fig7. of results for the bar magnet at temperature of 50 degreecelcius

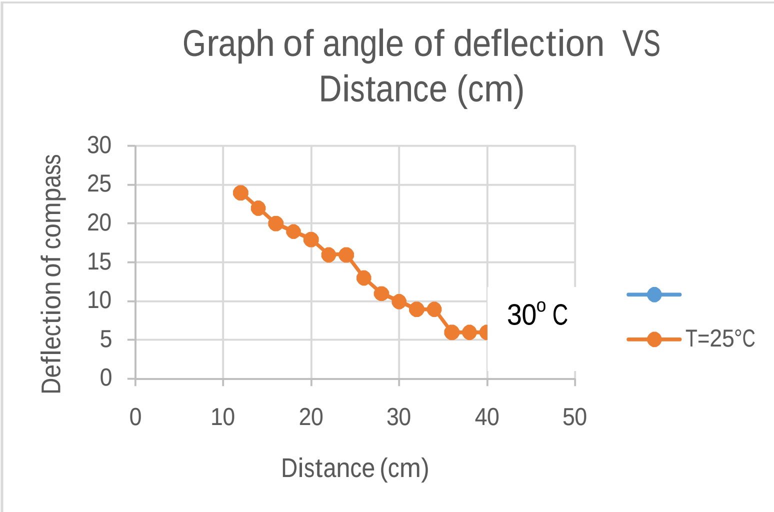


Fig 8. of results for the bar magnet at temperature of 30\

degree celcius

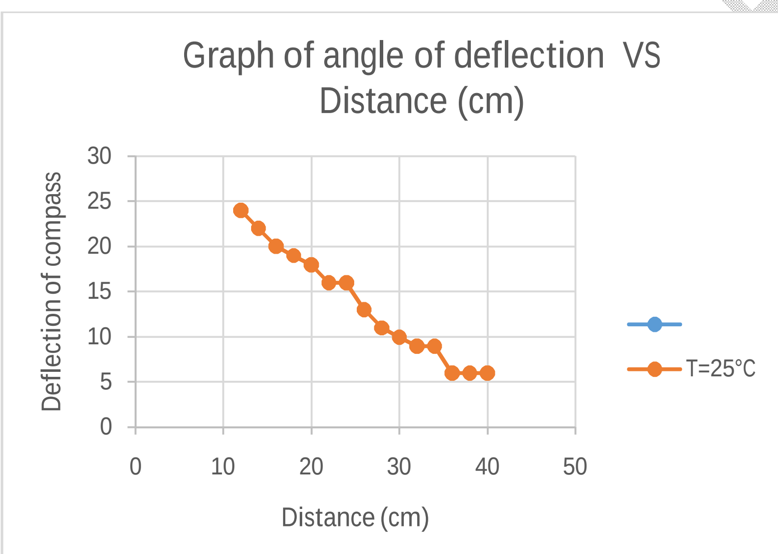


Fig.9: of results for the bar magnet at temperature of 25 degreecelcius

List 1 :In generally the table of results and graphs are summarized below as follows

		ANGLE OF DEFLECION OF COMPASS AT DIFFERENT TEMPERATURES (T's)						
DISTANCE (CM)		T1=25°C	T2=30°C	T3=50°C	T4=70°C	T5=90°C	T6=98°C	
40		6	5	3	3	0	0	
38		6	5	3	3	2	1	
36		6	5	3	3	2	1	
34		9	6	5	4	3	1	
32		9	6	5	4	3	2	
30		10	7	5	4	4	2	
28		11	7	7	6	5	3	
26		13	9	7	6	5	3	
24		16	9	8	6	5	4	
22		16	11	11	7	6	5	
20		18	13	13	9	6	5	
18		19	15	16	12	7	6	
16		20	17	18	17	8	7	
14		22	19	19	17	10	8	
12		24	23	20	18	12	10	

From these results at the distance of 40cm the angle of deflection is 6 at a temperature of 25°C, from that as temperature increase at the same distance the angle of deflection decease for example at 70°C the angle of deflection is 3 which show that as temperature increases the strength of the magnet decrease.

Its graphs are shown as shown below

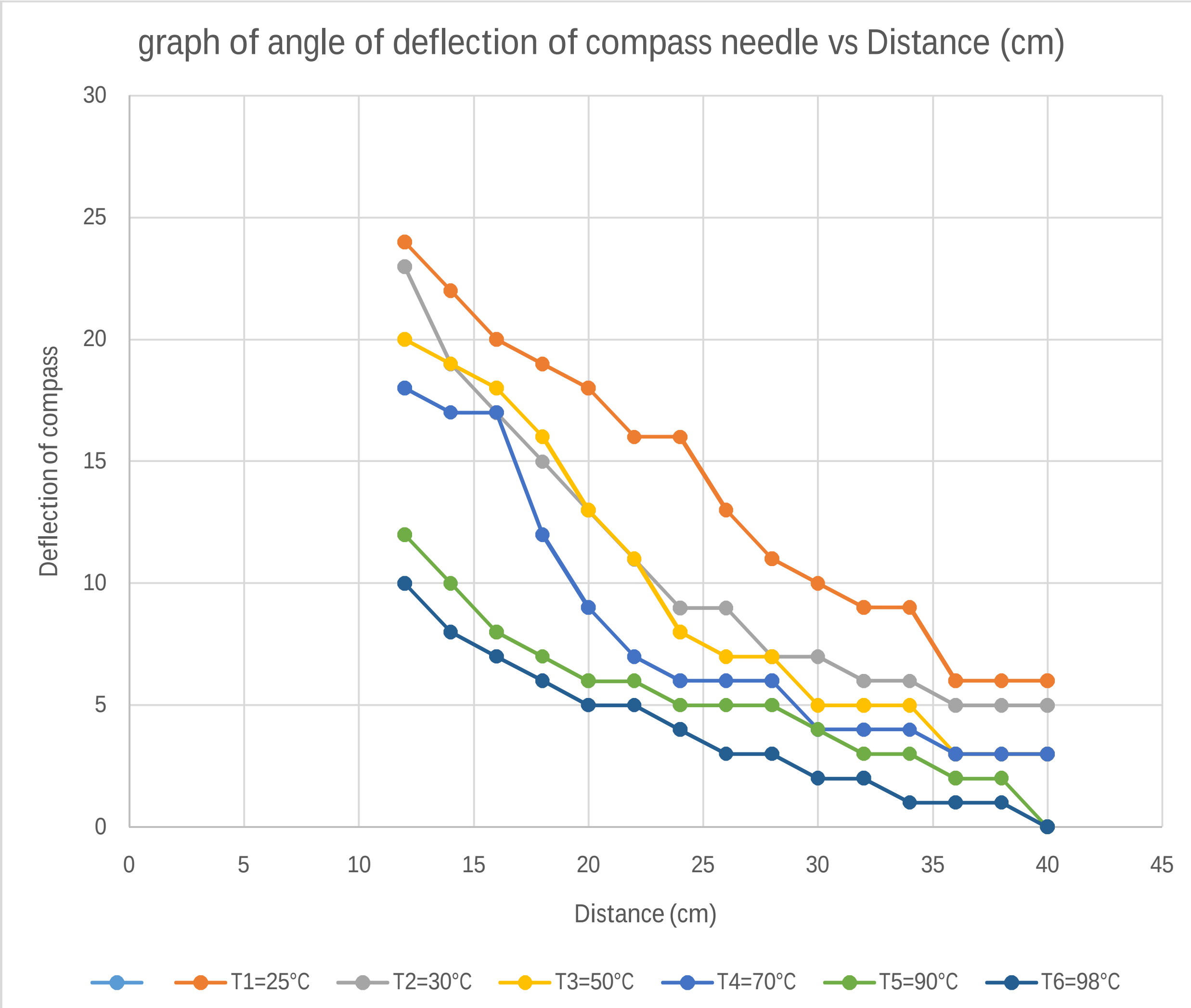


Fig 10. results for the bar magnet at various temperatures (degree celcius)

To understand temperature effects, we need to look at the atomic structure of the elements that make up the magnet. Temperature affects magnetism by either strengthening or weakening a magnet's attractive force. A magnet subjected to heat experiences a reduction in its magnetic field as the particles within the magnet are moving at an increasingly faster and more sporadic rate. This jumbling confuses and misaligns the magnetic domains, causing the magnetism to decrease. Conversely, when the same magnet is exposed to low temperatures, its magnetic property is enhanced and the strength increases.

In addition to the strength of the magnet, the ease at which it can be demagnetized also varies with temperature. Like magnet strength, demagnetization resistance generally decreases with increasing temperature. The one exception is ceramic (ferrite) magnets, which are easier to demagnetize at low temperature and harder to demagnetize at high temperature.

Different magnet materials react differently with temperature. Alnico magnets have the best strength stability followed by SmCo, NdFeB, and then ceramic. NdFeB magnets having the highest resistance to demagnetization (coercivity), but the largest change with temperature. Alnico magnets have the lowest resistance to demagnetization, but the smallest change with temperature. Alnico have the highest service temperature followed by SmCo, ceramic and then NdFeB.

Not everyone realizes that the shape of a magnet affects its maximum usable temperature. This is especially important for NdFeB magnets because they have the greatest change in demagnetization resistance with temperature. As the length of the magnetized axis increases, its resistance to demagnetization also increases.

In everyday language, we usually refer to magnets, and materials that are attracted to magnets, as *magnetic*. Technically, these materials are called ferromagnetic. Not all metals are ferromagnetic. Try to pick up a copper penny or a piece of aluminum foil with your magnet. Does it work? The most common ferromagnetic metals are iron, nickel, and cobalt. They are special because at the microscopic level, they contain many tiny magnetic domains. Each magnetic domain is like a tiny magnet with a *north* and *south pole*. Normally, the tiny magnetic forces created in those domains point randomly in all directions, so they cancel each other out, and as a result the material will not exert a magnetic push or pull on other ferromagnetic materials. However, when the material is placed in a strong magnetic field, the material gets magnetized, and all of these tiny magnetic fields line up, creating an overall larger magnetic field, as illustrated in Figure 11, below. To learn even more about magnets, check out the Science Buddies Electricity, Magnetism, & Electromagnetism Tutorial.

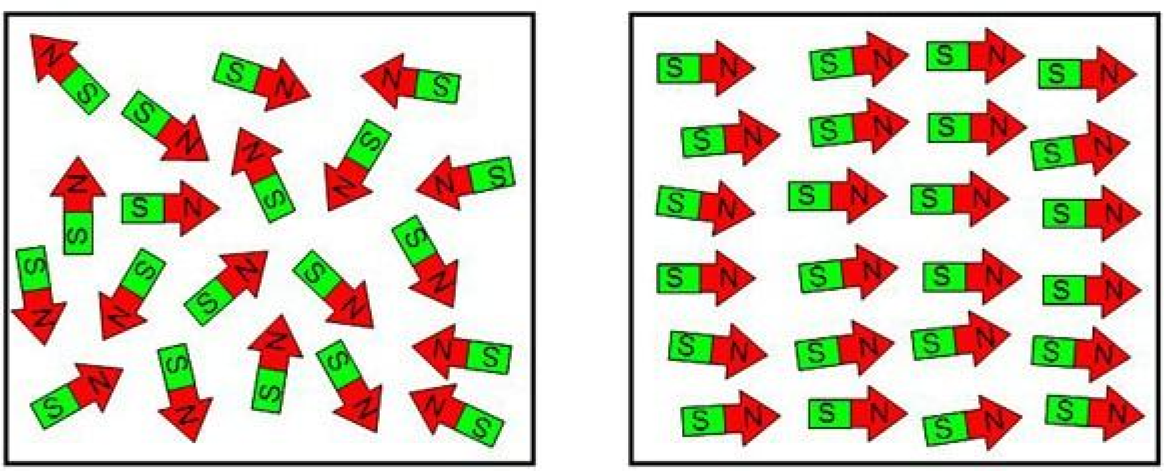


Image Credit: Ben Finio, Science Buddies / Science Buddies
Figure11. In ferromagnetic material, tiny magnetic domains act like tiny magnets. They can be oriented randomly in different directions, canceling each other out (left) or they can line up and all point in the same direction (right). When they line up, they combine and create a large magnetic force field, which allows the magnet to exert a magnetic force on other ferromagnetic materials.

Now, what would happen if you heated up the magnet? Scientists define the **temperature** of a material as a measure of random movement of atoms or molecules (the tiny particles the material is made of) within the material. Even when you see a solid block of metal, the atoms within this solid block are constantly vibrating back and forth. They move a little less when the block is cold, and a little more when the block is warm. Because heating up the block increases the random motion within the metal, would it also affect the alignment of magnetic domains? If so, an increase in the temperature of a magnet would tend to decrease its strength. In fact, each ferromagnetic material has a *Curie temperature* (named after Pierre Curie), above which it can no longer be magnetized. For some metals, like iron, the Curie temperature is over 1,300°C! Your oven at home might get as hot as 260°C, so obviously 1,300°C is out of the question for a science project. But what happens to the strength of a magnet over a more approachable range of temperatures, like from the temperature of your freezer (about −20°C) to the temperature of boiling water (+100°C)? In this science project, you will find out. The magnetic field strength depends on temperature. The magnetic field strength decreases with an increase in temperature. With an increase in temperature, there is a misalignment in the domains. This decreases the magnetic field strength.

5. CONCLUSION AND RECOMMEDATION

Heating the magnet will cause the magnet to have weaker magnetic field, cooling the magnet will cause a magnet to have stronger magnetic field. Cool magnets can be far away from the compass than hot magnets when they make the compass needle move. The results of the testing show that the magnet at low temperature deflect the needle of the compass at high distance compared to the magnet at high temperature.

Magnetic materials should maintain a balance between temperature and magnetic domains (the atoms'inclination to spin in a certain direction). When exposed to extreme temperatures, however, this destabilized, magnetic properties are then affected, while cold strength magnet, heat can result in the loss of magnetic properties. In other words, too much heat can completely ruin a magnet. Excessive heat cause atoms to move more rapidly, disturbing the magnetic domains, as the atoms are speed up the percentage of magnetic domains spinning in the same direction decreases. This lack of cohesion weakens the magnetic force and eventually demagnetizes it entirely, in contrast, when a magnet exposed to the low temperature, the atoms slow down so that the magnetic domains are aligned and, in turn, strengthened.

Temperature heavily impacts magnets. Permanent magnets like iron or neodymium lose all magnetism above the Curie point. Colder temperature improves their field strength.
Electromagnets gradually weaken when hotter due to lower electrical conductivity. But cold boosts superconducting electromagnets to very high fields. Careful temperature control is vital. Keeping permanent magnets away from extreme heat preserves magnetism.
Cooling electromagnets enables stronger magnetic fields. Harnessing hot and cold unlocks new magnetic applications across science, medicine, and engineering.

This is a neodymium magnet. It's pretty darn strong. And now, after heating it in a flame, it's no longer magnetic. What just happened?

Well, to build a magnet, all you need to do is find a bunch of magnetic atoms-- that's easy, they're the ones with the half-filled electron shells in the middle of any of the major blocks of the periodic table-- and then make a compound where the magnetic fields of the atoms align in the same direction. This is ferromagnetism, named after iron, which is pretty darn magnetic.

However, it's not always so easy. Sometimes the atoms actually want to align their magnetic fields in alternating directions. This is called anti-ferromagnetism, and it means the bulk material won't have a magnetic field at all. Or sometimes the tendency of the atomic magnets to align or anti-align is just too weak to overcome their intrinsic jiggling-- that is, their temperature. In which case, even though all the individual atoms in the material are magnetic, the material as a whole, again, isn't.

However, in a strong external magnetic field, the atoms do tend to align with each other in the direction parallel to the field. This is called paramagnetism, and liquid oxygen is a great example. It's attracted by a magnet, though it doesn't stay magnetized afterwards.

But let's get back to the question-- how do you destroy a magnet? Well, a material can only be ferromagnetic if its temperature is low enough. Above a certain point, the nicely ordered atomic magnetic fields melt into disorder, just as ice crystals melt into water when heated past 0 Celsius.

So to destroy a magnet, you just need to heat it up past its magnetic melting point, called the Curie temperature. It probably won't look like much is happening, but once the atoms are jiggling around enough, their magnetic fields will no longer all point in the same direction. Magnet destroyed.

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