Magnetism Lab
Nvis 6004

Learning Material
Ver 1.0

An ISO 9001: 2008 company

Designed & Manufactured in India by :

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CERTIFICATE OF COMPLIANCE

ICS

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This is to certify that the

QUALITY MANAGEMENT SYSTEM of

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141-A, Electronic Complex, Pardesipura, Indore - 452 010,
Madhya Pradesh, India.

has been assessed and registered as complying with the requirements of the following International Standard:

ISO 9001:2015

The Quality Management System applicable to:

Scope : Design And Manufacture Of Didactic Products And Clean Technologies Products Such As Solar Solutions.

Registration No.	:	**RQ91/7763**
Registered Date	:	**17th June, 2012**
Reassessment Date	:	**28th June, 2018**
Issue Date	:	**30th June, 2018**
Expiry Date	:	**16th June, 2021**

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Validity of this certificate is based on periodic audits of the management system defined by the above scope and is contingent upon prompt, written notification of significant changes to the management system and/or its components thereof shall be immediately communicated to ICS.
Further clarifications regarding the scope of this certificate and the applicability of ISO 9001:2015 requirements may be obtained at www.icsasian.com

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Magnetism Lab
Nvis 6004
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Introduction

Nvis Magnetism Lab Nvis 6004 is a versatile training system to be used in laboratories. It introduces the basic concepts of magnetism and provides a good basis for understanding the fundamentals of magnetism. This kit is provided with different types of materials and shapes of magnet, Magnetic Field Demonstrator, Lenz's Law Demonstrator, Homopolar Motor, Floating ring magnet setup and basic experiments of combined magnetic field of earth and magnet and magnetic effects of current.

Magnetism is the force where objects are attracted or repelled to one another. Usually these objects are metals such as iron. Every magnet has two poles-North and South Pole. So these opposite poles of magnet shows attraction and repulsion properties of magnet.

Various shapes of magnets like bar, U, horse shoe, cylindrical, ring and disk are provided with this kit. This will make students to know different shapes of magnets used in our daily life for domestic and industrial purposes. Magnets are of different material like alnico, ceramic or ferrite and rare earth (neodymium).

Magnetic Field Demonstrator is used to demonstrate magnetic field lines of magnet and pattern of electrons in a magnetic field. The region around a magnet in which it exerts forces on other magnets and on objects made of iron is called a magnetic field. It originates from North Pole and ends at South Pole.

Lenz's Law Apparatus dramatically shows that due to change in magnetic field, induced emf is produced and this induced emf opposes the change that is producing it. It is showed by strong neodymium magnet.

Homopolar Motor is the simplest motor designed to demonstrate the principle of motor in a very simple way.

Floating ring magnet with wooden dowel is designed to study magnetic levitation on which modern maglev trains are based. This apparatus helps students to understand Earns haw's Theorem.

Magnetism Lab

Features

- **Complete training system to study the fundamentals of magnetism**
- **Provided with easiest way of magnetic field demonstration**
- **Dramatic demonstration of Lenz's Law**
- **Homopolar motor demonstration**
- **Provided with floating ring magnets and a dowel to demonstrate magnetic levitation**
- **Provided in a good quality carrying case with foam inserts**

Technical Specifications

Magnetism Lab is provided with following contents:

1. **Bar Magnet (Alnico)**
2. **Cylindrical Magnet (Alnico)**
3. **U-shape Magnet (Alnico)**
4. **Horse shoe Magnet (Alnico)**
5. **Ring Magnet (Ceramic or ferrite)**
6. **Disc Magnet**
    - Ceramic or ferrite
    - Neodymium-Iron-Boron (NIB)
7. **Magnetic Compass**
8. **Magnetic Field Demonstrator**
9. **Lenz's Law Demonstrator**
10. **Motor Assembly with a battery**
11. **Dowel**
12. **Coil**
    - No. of Turns : 400
    - Inductance (approx.) : 2.3mH
    - Maximum Current : 0.728
13. **Iron Nail**
14. **Patch cord**

Safety Instructions

Read the following safety instructions carefully before operating the instrument. To avoid any personal injury or damage to the instrument or any product connected to the instrument.

Do not operate the instrument if suspect any damage to it.

The instrument should be serviced by qualified personnel only.

For your safety:

Use proper Mains cord : Use only the mains cord designed for this instrument. Ensure that the mains cord is suitable for your country.

Ground the Instrument : This instrument is grounded through the protective earth conductor of the mains cord. To avoid electric shock, the grounding conductor must be connected to the earth ground. Before making connections to the input terminals, ensure that the instrument is properly grounded.

Use in proper Atmosphere : Please refer to operating conditions given in the manual.

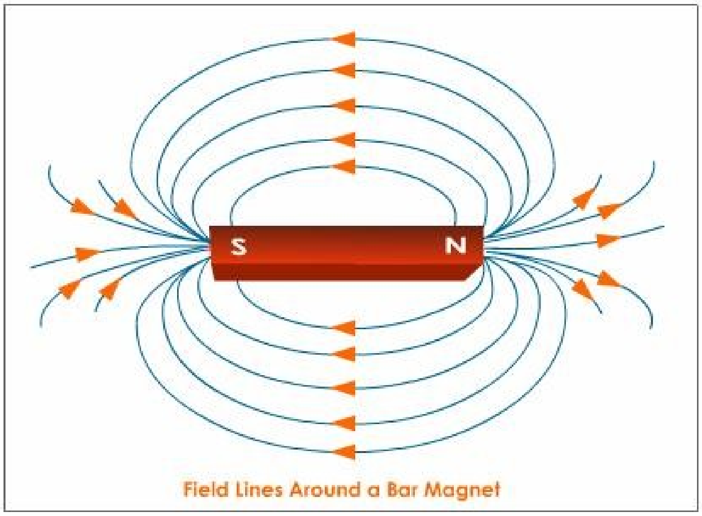
1. **Do not operate in wet / damp conditions.**
2. **Do not operate in an explosive atmosphere.**
3. **Keep the product dust free, clean and dry.**

Theory

Magnetism is the force where objects are attracted or repelled to one another. Usually these objects are metals such as iron. The substance having property of magnetism is called magnet. Every magnet has two poles. At the poles magnetic strength is most powerful. These poles are called north and south or north-seeking and south seeking poles. The poles are called this as when a magnet is hung or suspended the magnet lines up in a north (-) south direction. When the north pole of one magnet is placed near the north pole of another magnet, the poles are repelled. When the south poles of two magnets are placed near to each other they are also repelled. When the north and south poles of two magnets are placed near to each, they are attracted to one another. The attraction and repulsion of two magnets towards one another depends on how close they are to each other and how strong the magnetic force is within the magnet. On increasing distance between two magnets they are less attracted or repelled.

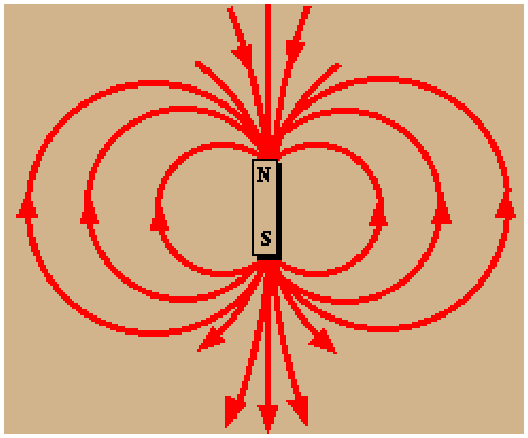
When a magnet is broken into little pieces, a north pole will appear at one of the broken faces and a south pole. Each piece, regardless of how big or small, has its own north and south poles. The area around a magnet can also behave like a magnet. This is called a magnetic field. The larger the magnet and the closer the object to the magnet, the greater the force of the magnetic field.

A magnet with two poles, such as a bar magnet, is called a magnetic dipole. One end points to the north & is considered the North Pole, the end that points to the south is considered the South Pole. The best way to visualize these two poles is to cut a magnet in half, creating a north pole and a south pole.



Magnetic field Lines of a Bar Magnet

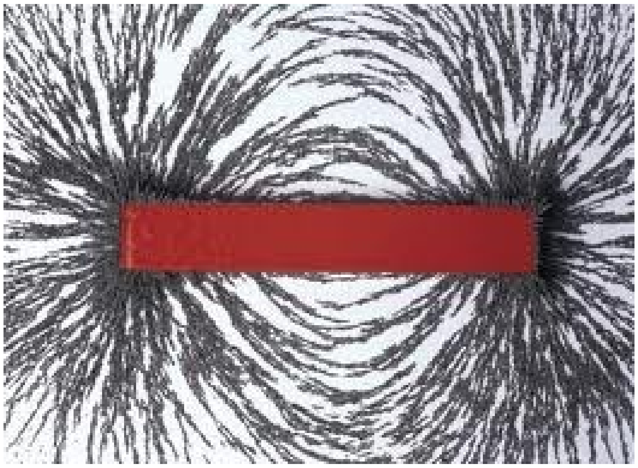
Lines of force are three-dimensional, surrounding a bar magnet on all sides. When opposite poles of a magnet are brought together, the lines of force join up and the magnets pull together.



Courtsy :
http://www.vernonpratt.com/222/22208instrumentalism1.htm

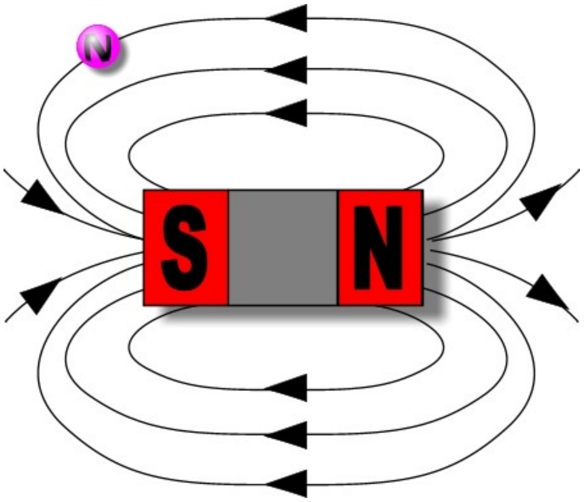
If the north pole of a magnet is brought near the south pole of another magnet, the magnetic force will pull the magnets together. However, two north poles or two south poles brought together would repel each other. In other words, like repels like and the old saying, opposites attract. That would be explained by what is known as the magnetic field. The magnetic field around a magnet is where the force of the magnetism can be felt. It is invisible, but you can get an idea of what it looks like by this simple example.

Take a magnet and place a piece of paper over it. On top of the paper (and above the magnet) sprinkle iron fillings. The fillings arrange themselves along the lines of the magnetic force, making the lines visible.



Magnetic field lines of a Bar Magnet Using iron fillings

A magnetic force can also be thought of as set of imaginary lines called lines of force. These lines are thought of as going out from the north pole of a magnet, looping around, and returning to the magnet at its south pole. The magnetic field is the strongest at the poles and is where the lines lie closest to each other. This explains why a compass works. The needle of a compass is actually a magnet. It normally points north along one of the earths magnetic field lines. But a strong bar magnet placed next to the compass will cause the needle to point along the bar magnet but with opposite pole to that of magnet pointing towards the magnet.



http://resources.yesican-science.ca/magnets/animate1.html

Repulsion- Surest Test of Magnetization

An iron rod is attracted towards a magnet. The opposite poles also attract each other. So, attraction is not a sure test of magnetization. On the other hand, if there is repulsion between a magnet and a given rod, we can be sure that the given rod is magnetized.

History of Magnetism

The term magnetism is derived from Magnesia, the name of a region in Asia Minor where lodestone, a naturally magnetic iron ore, was found in ancient times. Iron is not the only material that is easily magnetized when placed in a magnetic field; others include nickel and cobalt.

Magnets were discovered independently by the people in China and Greece. They had found that natural lodestone magnets attracted iron. The Chinese also found that a piece of loadstone would point in a north-south direction if it was allowed to rotate freely. This was how they told fortunes and also what they used as a guide for building. By A.D. 1200, the Chinese and Europeans had realized the uses behind this magical stone and they began using it on their ships as compasses to steer.

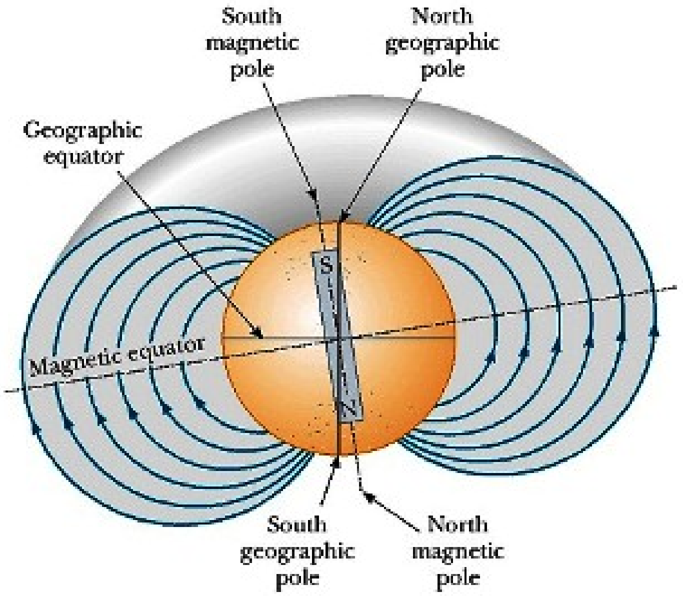
In 1269, a French soldier named Pierre de Mari court mapped the magnetic field around a lodestone sphere with a compass. It was then discovered that a magnet has two poles. And later in 1600, the earth itself was recognized as having two poles by a physician of Queen Elizabeth I of England, named William Gilbert.

Hans Christian Oersted in 1820, a Danish physicist observed that an electric current flowing in a wire caused the needle of a magnetic compass to rotate. His discovery proved that electricity and magnetism were related.

Then, in the early 1830's, the English scientist Michael Faraday and the American physicist Joseph Henr y independently discovered that a changing magnetic field induced a current in a coil of wire. This discovery led to the electric motor meters which would eventually bring about electric powered radio and television.

Terrestrial Magnetism (Magnetism of Earth)

The branch of Physics which deals with the study of earth's magnetic field is called terrestrial magnetism it is also called geomagnetism.



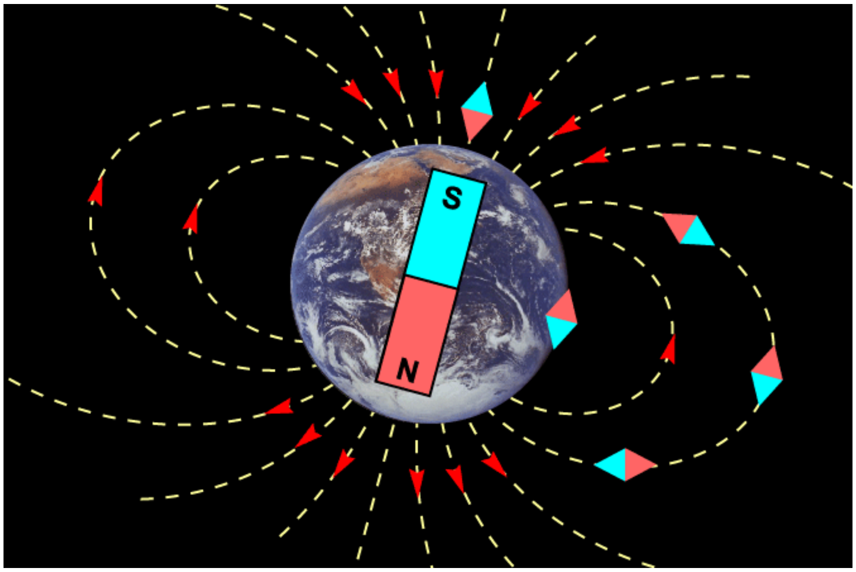
The Earth's magnetic field lines. Note that a south magnetic pole is near the north geographic pole, and a north magnetic pole is near the south geographic pole.

Earth's magnetic field

Many centuries ago, it was observed that the lodestone and the artificial magnets, when freely suspended, stay in the north-south direction. It was thought that the pole star exerts some sort of a force on the magnets. In about 1600, William Gilbert, who was a physician to Queen Elizabeth I of England, showed that the force acting on a suspended magnet is not due to the influence of the pole star but due to a magnetic field which is present all over the surface of the earth, as if the earth was magnetized. Gilbert made a large spherical ball from magnetite, the poles of which were situated on two opposite ends. By placing a small magnetic compass on this magnetite sphere, Gilbert showed that the compass took up a definite direction at different points on the sphere as it does in the case of the earth. According to his view, the magnetic field on the surface of the earth can be approximately represented as if caused by a huge imaginary bar magnet in the interior of the earth but inclined to the geographic north and south axis of the earth. The concept of terrestrial magnetism has been illustrated in above Fig. The north end of the imaginary magnet has been assigned a south polarity while the south end has been assigned the north polarity.

Note : The magnetic north pole is actually a south pole of the 'imaginary magnet' and the magnetic South Pole is actually a north pole of the 'imaginary magnet'. The magnetic north and south poles have not been named after the poles of the imaginary magnet. These have been named after the directions taken up by a magnetic needle free to move in a horizontal plane. Thus, we can say that the magnetic pole near North (geographical) pole has a south polarity, because it attracts North Pole of suspended magnet towards it and the magnetic pole near South (geographical) pole has a north polarity, because it attracts South Pole of suspended magnet towards it. The magnetic field of the earth exerts a torque on freely suspended magnet (magnetic needle or compass needle) which makes the needle to align itself in North-South direction.

The magnetic field of earth extends many thousand miles into the space around the earth. The magnetic field at the surface of earth ranges from nearly 30µT near the equator to about 60µT near the poles. It is interesting to note that the magnetic field on the axis is twice the magnetic field on the equatorial line.



As discussed earlier, the observed magnetism of the earth can be roughly portrayed as if it were due to a huge bar magnet within the earth, with its axis displaced nearly 20° from the earth's axis and considerably shorter than the earth's diameter. It may be pointed out here that over geological time periods like tens of thousands of year, the' angle' does change i.e., the earth's magnetic axis has been shifting off and on. Whilethe magnetic north pole of the earth is located somewhere in Antarctica, the tip of the magnetic axis corresponding to the earth's magnetic South Pole is located at a point in Northern Canada 95° W 70.5°

N. Both the magnetic poles are at considerable distances from the geographical poles. A great circle around the earth perpendicular to the magnetic axis is known as magnetic equator. It happens to pass through India, infact near Trivandrum.

The strength of the magnetic field of the earth is of the order of “1oersted” or “gauss” (10^{-4}T). The strength and direction of the earth's magnetic field not only vary from place to place but also vary in time. There is a very small and periodic daily variation, an even smaller annual variation but a very considerable, though erratic, secular variation or long time change. Large and very erratic variations occur at certain times. These are known as magnetic storms. They do not necessarily occur simultaneously with meteorological storms but are probably related to variations in electric currents in the earth's atmosphere. There is correlation in time between magnetic storms and the occurrence of sunspots and it is generally agreed that the two are intimately related.

The facts of terrestrial magnetism are so complex and the observed-data are comparatively so meager and contradictory that theories as to the origin and nature of the earth's magnetism are not at present on a firm basis.

However, a brief review is as under

The oldest theory was proposed by Gilbert. According to this theory, the earth’s magnetism is due to presence of a large quantity of magnetite. But this theory had to be discarded because a very small quantity of magnetite is found in earth's crust. It was then assumed that the earth contains a large amount of ferromagnetic material. But the temperature in the interior of the earth is so high that the ferromagnetic material cannot retain its magnetization. In the year 1676, Bond suggested that the earth is surrounded by a magnetic sphere. In the year 1692, Halley suggested that the earth consists of two magnetic shells having different rates of rotation. Sir Bullard in England and Elasser in USA suggested that the source of geomagnetism is within the earth itself. It is caused by electric current in the earth’s liquid core at a depth of nearly 3000 km.

No one knows for sure, but there is a working theory currently. The Earth's core is thought to consist largely of molten iron (red). But at the very core, the pressure is so great that this super hot iron crystallizes into a solid.

Convection caused by heat radiating from the core, along with the rotation of the Earth, causes the liquid iron to move in a rotational pattern. It is believed that these rotational forces in the liquid iron layer lead to weak magnetic forces around the axis of spin.

A spectacular effect due to Earth's Magnetism

Magnetic fields extend infinitely, though they are weaker further from their source. As the Earth's magnetic field extends several tens of thousands of kilometres from Earth, into space, it is called the magnetosphere.

The magnetosphere is that area of space, around the Earth, that is controlled by the Earth's magnetic field. The Earth has a magnetic field with north and south poles.

So we can say that the Earth's environment extends all the way from the sun to the Earth and beyond. It is not an empty wasteland of space. Instead, near-Earth space is full of streaming particles, electromagnetic radiation, and constantly changing electric and magnetic fields. All of these things make up our magnetosphere.

It is important to learn as much about this space around the Earth as we would about any other part of the Earth's environment. The magnetosphere helps to protect our Earth from the danger of the Sun's solar wind. The magnetosphere prevents most of the particles from the sun, carried in solar wind, from hitting the Earth. The sun is flinging 1 million tons of matter out into space every second!

We call this material solar wind. Once the solar wind is blown into space, the particles travel at supersonic speeds of 200-800 km/sec! These particles travel all the way past Pluto and do not slow down until they reach the termination shock within the heliosphere. The Heliosphere is the entire region of space influenced by the Sun.

The solar wind plasma is very thin. Near the Earth, the plasma is only about 6 particles per cubic centimeter. So, even though the wind travels SUPER fast, it wouldn't even ruffle your hair if you were to stand in it because it's so thin. But, it is responsible for such unusual things as :

Auroral lights

Fueling magnetospheric storms

Forming a planet's magnetosphere

The particles of the solar wind, and the Sun's magnetic field (IMF) are stuck together, therefore the solar wind carries the IMF (interplanetary magnetic field) with it into space.

Auroral lights

Some particles from the solar wind can enters the magnetosphere. The particles that enter from the magnetotail travel toward the Earth and create the auroral oval light shows. In the arctic regions, near the magnetic poles of earth, a spectacular effect caused by earth’s magnetism is seen. This effect is called 'aurora borealis' in the north and 'aurora australis' in the south. It consists of huge patterns of colored lights. It is because of the fact that solar wind (streams of electrons and protons) gets trapped near the magnetic poles, above the atmosphere. On the way down, this wind ionizes the molecules of the atmosphere giving out light which constitutes the aurora. The aurora is also known as the northern and southern lights. From the ground, they can usually be seen where the northern and southern auroral ovals are on the Earth.

The northern polar auroral oval usually spans Fairbanks, Alaska, Oslo, Norway, and the

Northwest Territories. Sometimes, when the Sun is active, the northern auroral oval expands and the aurora can be seen much farther south. The aurora which is found at the equator is called the equatorial arcs.

Geomagnetic Storms

From May 1806 until June 1807, from his home in Berlin, Baron Alexander von Humboldt observed which way the magnetic needle was pointing. On December 21,1806, he recorded strong magnetic disturbances. The same night he saw auroral lights. In the morning, the aurora was gone, the magnetic disturbances were gone.
Humboldt was left though with his discovery of the geomagnetic storm.A geomagnetic storm is just what Humboldt recorded, a disturbance of the Earth's magnetic field.

The solar wind carries with it the magnetic field of the Sun. This magnetic field or the IMF (interplanetary magnetic field) has a particular orientation - southward or northward.
If the IMF of the solar wind is southward and the solar wind crosses the Earth for long periods of time, geomagnetic storms can be expected. The southward IMF causes magnetic and particle energy to be injected into the Earth's magnetosphere creating storms.

Just in the last 30 years have scientists truly begun to understand the coupled Sun-Earth system. Many of the improved theories are due to satellites such as Yohkoh and Ulysses. It is extremely important to understand such storms because of the effects they have on life on Earth. Geomagnetic storms can affect radio communication, satellite drag, auroral activity and even the safety of astronauts in Earth orbit.

Magnetosphere

A magnetosphere has many parts, such as the bow shock, magneto sheath, magneto tail, plasma sheet, lobes, plasma sphere, radiation belts and many electric currents. It is composed of charged particles and magnetic flux.

These particles are responsible for many wonderful natural phenomena such as the aurora and natural radio emissions such as lion roars and whistler waves.
The particles move and circulate about the magnetosphere and even generate storms. The magnetosphere changes constantly, even flipping its orientation every few thousand years.

What does a Magnet Attract?

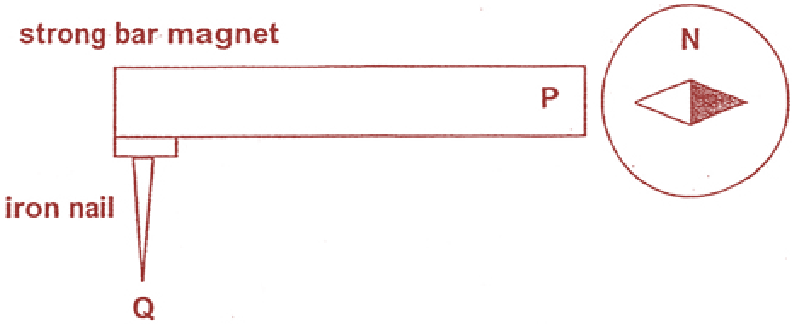
A magnet attracts iron, steel, nickel, and certain other materials. The attracted materials then become magnets themselves in a process called magnetization. For example, if you were to place a nail near a magnet, it would become magnetized and would then attract a second nail. Magnetization occurs because the magnet causes particles called electrons in the atoms of the nail to align along the magnet's lines of force. The atoms with aligned electrons then act like tiny bar magnets themselves.

Types of Magnets :

There are 3 main types of magnets,

1. Temporary magnets
2. Permanent magnets and
3. Electromagnets

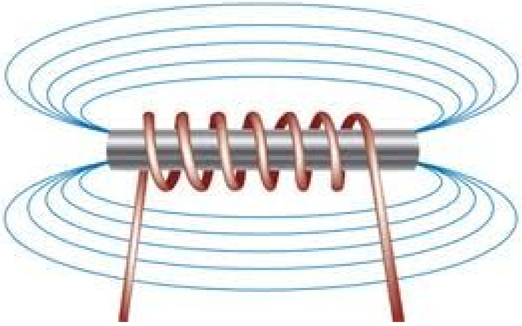
Temporary Magnets: Temporary magnets are just that, temporary. They are made of such materials as iron and nickel. These materials are known as soft magnetic materials because they usually do not retain their magnetism once removed form a strong magnetic field. For example, once you remove the nail from the strong magnet near it, it will lose its magnetic ability to attract other nails.



Permanent Magnets: Permanent magnets are magnets that keep their magnetism after they've been removed from a strong magnetic field. They are therefore known as hard magnetic materials. Examples are alloys (mixtures) of iron, nickel or cobalt mixed with other elements. Alloys that contain the rare-earth elements have produced some of the strongest permanent magnets. Examples of the rare-earth elements are: samarium and neodymium.

There are a few soft magnetic materials that can be made into weak permanent magnets. An iron needle for a compass, for example, can be permanently magnetized by stroking it in one direction with a magnet.

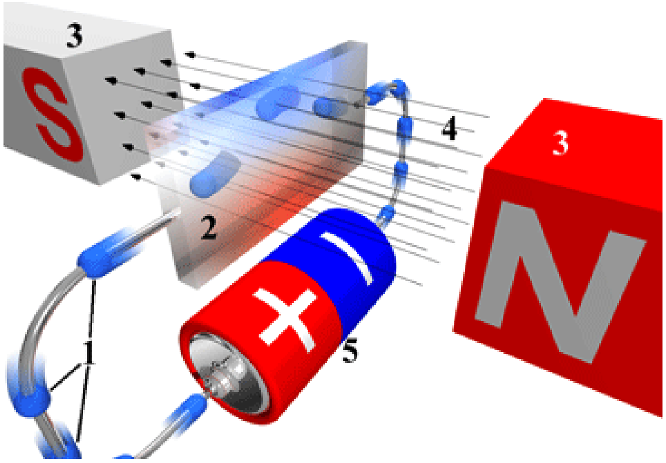
Electromagnets : Electromagnets are temporary magnets produced by electric currents (DC supply). The simplest electromagnets consist of electric current (DC supply) flowing through a cylindrical coil of wire called a solenoid. One end of the solenoid becomes the North Pole and the other becomes the South Pole. The reversal of the current can cause the poles to switch position, and if supply is shut off, the solenoid will lose its magnetism.



Actually, when connected to a DC voltage or current source, the electromagnet becomes energized, creating a magnetic field just like a permanent magnet. So electromagnet works only when supply is present.

History of Electromagnets:

William Sturgeon, a British electrician, built the first practical electromagnet in 1825. This was a device in which magnetism could be generated using an electric current. The apparatus was a horse-shoe shaped piece of iron wrapped with a coil, so that when a current was passed through the coil, the horse-shoe shaped electromagnet became magnetized. Indeed, when the current was cut, the electromagnet lost its magnetic field. In 1830, Joseph Henry created a more powerful electromagnet. The electromagnet was used to send pulses of current over wire, which in turn, caused a bell to ring. The telegraph was born. Sturgeon’s new technology allowed for the use of electrical energy to control machines; it laid the foundation for future large-scale electrical communications.



Applications of Electromagnets

The discovery of electromagnetism led to a large number of inventions and devices. Being able to turn magnetism on and off, the great strength of electromagnets, and being able to vary the magnetism by varying the electrical current are characteristics of electromagnetism used in many inventions. Some devices reverse the characteristics to create another class of devices.

Doorbells, cathode ray tubes, particle beams, and devices used to lift scrap metal all employ electromagnets. Electromagnets are also used in cars, in the braking and clutch. Modern engineers have applied electromagnetic technology to other unessential walks of life. Roller coasters often use electromagnets to propel the car at very high speeds. Trams use electromagnets to firmly grasp the rails. All of these modern devices employ some form of variation in the field strength/current, making an electromagnet advantageous. A more modern application of the electromagnet is magnetic levitation transport, or maglev.

Maglev is a possible alternate form of mass transportation to regular trains. Maglevs are "levitated" trains, guided and propelled by electromagnets. Ideally, they could reach speeds of just over 400 mph, at a relatively cheap energy cost, rivaling short distance airline flights.

However, economic and spatial restrictions have made Maglevs difficult to come by. They are expensive to build and are not compatible with conventional railroad tracks; thus, an entirely new system must be put in place whenever a Maglev is built. The world's first commercial Maglev was built in Shanghai.

General Applications of Electromagnet

1. Lifting and dropping objects: The magnetic strength of an electromagnet depends on the number of turns or wire and the current through the wire, and the size of the iron core. This allows electromagnets to be made much larger and stronger than a natural magnet, such that they can pick up very large objects.

Also, when you turn off the electricity to an electromagnet, the magnetism is also turned off. Thus, an electromagnet can be used to pick up a piece of iron and then drop it someplace else.

Strong electromagnets are often used in areas of heavy industry to move large pieces of iron or steel. They are commonly employed in junkyards, where a crane with a huge electromagnet is used to pick up, move and drop old, junked cars.

2. Loudspeaker : The loudspeakers in your radio, TV or stereo system use varying electric current through an electromagnet to create sound. The electric current varies at a fast rate, causing the strength of the magnetic field to vary. This results in moving the loudspeaker membrane or cone back and forth rapidly, resulting in sound and even music. Some loudspeakers use a solenoid instead of an electromagnet.

3. Electric Motor : An electric motor is an even more clever application of electromagnets. Suppose some electromagnets are put on a wheel and put some permanent magnets around the wheel. The electromagnets could be made to attract and repel the surrounding magnets, causing the wheel to turn. The internal wheel made of electromagnets and the outer shell made of permanent magnetic material.

4. Microphone: Loudspeaker can become a microphone. Suppose membrane of a loudspeaker or an earphone is vibrated with sound. The movement of the coiled wires or solenoid in the magnetic field would work just the opposite of a loudspeaker, and a varying electrical current would be created. Now this will be a microphone.

Types of Permanent Magnets

1.Ceramic

2.Alnico

3.Rare earth magnet

- Samarium Cobalt
- Neodymium Iron Boron

4.Injection-Molded

5.Flexible

Ceramic

Ceramic, also known as Ferrite, magnets are made of a composite of iron oxide and barium or strontium carbonate. These materials are readily available and at a lower cost than other types of materials used in permanent magnets making it desirable due to the lower cost. Ceramic magnets are made using pressing and sintering. These magnets are brittle and require diamond wheels if grinding is necessary. These magnets are also made in different grades. Ceramic-1 is an isotropic grade with equal magnetic properties in all directions. Ceramic grades 5 and 8 are anisotropic grades. Anisotropic magnets are magnetized in the direction of pressing. The anisotropic method delivers the highest energy product among ceramic magnets at values up to 3.5 MGOe (Mega Gauss Oersted). Ceramic magnets have a good balance of magnetic Strength, resistance to demagnetizing and economy. They are the most widely used magnets today.

Advantages	Disadvantages
Low Cost	Low Energy Product
High Coercive Force	Low Mechanical Strength - Brittle
High Resistance to Corrosion	

Alnico

Alnico magnets are made up of a composite of aluminum, nickel and cobalt with small amounts of other elements added to enhance the properties of the magnet. Alnico magnets have good temperature stability, good resistance to demagnetization due to shock but they are easily demagnetized.

Alnico magnets are produced by two typical methods, casting or sintering. Sintering offers superior mechanical characteristics, whereas casting delivers higher energy products (up to 5.5 MGOe) and allows for the design of intricate shapes. Two very common grades of Alnico magnets are 5 and 8. These are anisotropic grades and provide for a preferred direction of magnetic orientation. Alnico magnets have been replaced in many applications by ceramic and rare earth magnets.

Advantages	Disadvantages
High Corrosion Resistance	High Cost
High Mechanical Strength	Low Coercive Force
High Temperature Stability	Low Energy Product

Samarium Cobalt

Samarium cobalt is a type of rare earth magnet material that is highly resistant to oxidation, has a higher magnetic strength and temperature resistance than Alnico or Ceramic material. Introduced to the market in the 1970's, samarium cobalt magnets continue to be used today.

Samarium cobalt magnets are divided into two main groups: Sm1Co5 and Sm2Co17 (commonly referred to as 1-5 and 2-17). The energy product range for the 1-5 series is 15 to 22 MGOe, with the 2-17 series falling between 22 and 32 MGOe. These magnets offer the best temperature characteristics of all rare earth magnets and can withstand temperatures up to 300° C. Sintered samarium cobalt magnets are brittle and prone to chipping and cracking and may fracture when exposed to thermal shock. Due to the high cost of the material samarium, samarium cobalt magnets are used for applications where high temperature and corrosion resistance is critical.

Advantage	Disadvantages
High Corrosion Resistance	High
High Energy Product	Low Mechanical Strength - Brittle
High Temperature Stability	
High Coercive Force	

Neodymium Iron Boron (NdFeB)

Neodymium Iron Boron (NdFeB) is another type of rare earth magnetic material. This material has similar properties as the Samarium Cobalt except that it is more easily oxidized and generally doesn't have the same temperature resistance.

NdFeB magnets also have the highest energy products approaching 50MGOe. These materials are costly and are generally used in very selective applications due to the cost. Cost is also driven by existing intellectual property rights of the developers of this type of magnet. Their high energy products lend themselves to compact designs that result in innovative applications and lower manufacturing costs. NdFeB magnets are highly corrosive. Surface treatments have been developed that allow them to be used in most applications. These treatments include gold, nickel, zinc and tin plating and epoxy resin coating.

Advantage	Disadvantages
Very High Energy Product	Higher Cost (Except from us!)
High Coercive Force	Low Mechanical Strength - Brittle
	Moderate Temperature Stability
	Low Corrosion Resistance (When uncoated)

Injection Molded

Injection molded magnets are a composite of resin and magnetic powders of different materials allowing parts to be made in an injection molding process. Energy products are dependent upon the magnetic powders used in fabrication. The molding process allows for the manufacture of more complex shapes. These magnets are usually lower in magnetic strength as there are limitations to the degree of loading.

Advantage	Disadvantages
Moderate Energy Product	High
Moderate Coercive Force	Low Temperature Stability
High Corrosion Resistance	
Highly Shapeable	

Flexible

Flexible magnets are very similar to the injection molded magnets but are produced in flat strips and sheets. These magnets are lower in magnetic strength and very flexible depending on the materials that was used in the compound with the magnetic powders. Vinyl is often used in this type of magnet as the binder.

Advantage	Disadvantages
Low	Low Energy Product
High Corrosion Resistance	Low to Medium Temperature
Moderate Coercive Force	

Shapes of Magnet

Permanent magnets can be made in most any shape imaginary. They can be made into rectangular bars, round bars, horseshoes, U, Cylindrical, rings or donuts, disks, rectangles, multi-fingered rings, and other custom shapes. Some are cast into a mold and require grinding to achieve final dimensions. Others start as a powder which is pressed into a mold or pressure bonded or sintered.

Magnetic Compass

A compass is an instrument containing a freely suspended magnetic element (needle) which displays the direction of the horizontal component of the Earth's magnetic field at the point of observation.

History of Magnetic Compass

The magnetic compass is an old Chinese invention, probably first made in China during the Q in dynast y (221-206 B.C.). Chinese fortune tellers used lodestones (a mineral composed of an iron oxide which aligns itself in a north-south direction) to construct their fortune telling boards.

Eventually someone noticed that the lodestones were better at pointing out real directions, leading to the first compasses. They designed the compass on a square slab which had markings for the cardinal points and the constellations. The pointing needle was a lodestone spoon-shaped device, with a handle that would always point south.

Magnetized needles used as direction pointers instead of the spoon-shaped lodestones appeared in the 8th century AD, again in China, and between 850 and 1050 they seem to have become common as navigational devices on ships.

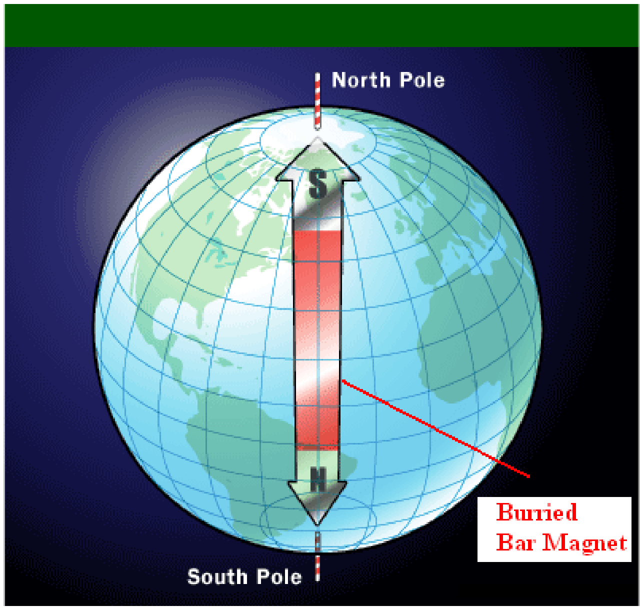
The first person recorded to have used the compass as a navigational aid was Zheng He (1371-1435), from the Yunnan province in China, who made seven ocean voyages between 1405 and 1433.

Theory of compass

A compass is an extremely simple device. It consists of a small, light weight magnet balanced on a nearly frictionless pivot point. The magnet is generally called a needle. One end of the needle is often marked “N," for north, or colored in some way to indicate that it points toward north. Generally red color is used to indicate north.

The reason why a compass works is more interesting. It turns out that you can think of the Earth as having a gigantic bar magnet buried inside. In order for the north end of the compass to point toward the North Pole, you have to assume that the buried bar magnet has its south end at the North Pole, as shown in the Fig.

If you think of the world this way, then you can see that the normal "opposites attract" rule of magnets would cause the north end of the compass needle to point towards the south end of the buried bar magnet. So the compass points towards the North P.



Bar Magnet imagined as buried inside Earth

To be completely accurate, the bar magnet does not run exactly along the Earth's rotational axis. It is skewed slightly off center. This skew is called the declination, and most good maps indicate what the declination is in different areas (since it changes a little depending on where you are on the planet).

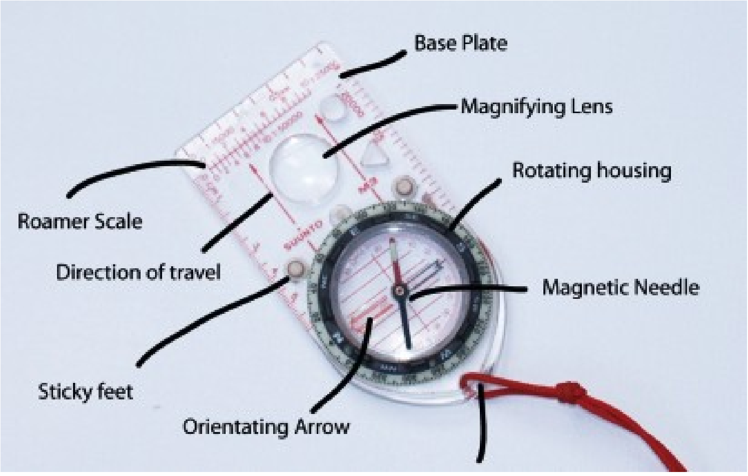
The magnetic field of the Earth is fairly weak on the surface. After all, the planet Earth is almost 8,000 miles in diameter, so the magnetic field has to travel a long way to affect your compass. That is why a compass needs to have a light weight magnet and a frictionless bearing. Otherwise, there just isn't enough strength in the Earth's magnetic field to turn the needle.

It turns out that because the Earth's magnetic field is so weak, a compass is nothing but a detector for very slight magnetic fields created by anything. That is why we can use a compass to detect the small magnetic field produced by a wire carrying a current.

The "big bar magnet buried in the core" analogy works to explain why the Earth has a magnetic field, but obviously that is not what is really happening.

Types of Compass

1. **Baseplate Compass (Orienteering Compass) :** This type of compass was developed by the Kjellstrom brothers and another keen orienteer, Gunnar Tillander in Sweden in the early 1930's. They combined a liquid-filled compass in a housing which could rotate over a protractor base. This saved a lot of time transferring bearings from compass to map. It proved to be a new and greatly successful system of direction- finding for outdoor activities. These compasses are made of clear plastic or perspex. They have a rectangular base with a 360° dial mounted upon it. Inside the raised dial is a magnetic needle suspended in clear fluid. The dial October be turned to read a correct bearing along the direction of travel arrow which is clearly marked on the base plate.

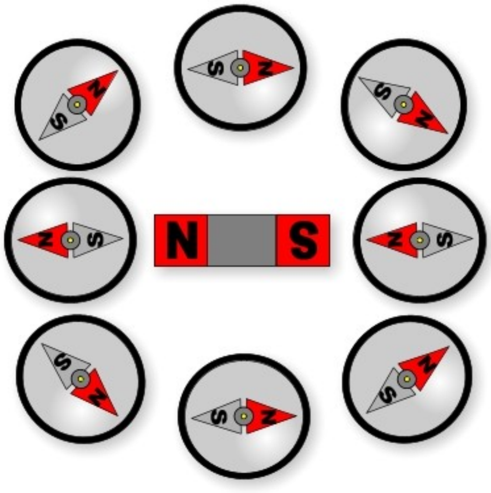


Baseplate Compass

2.Needle Compass (Pocket Compass) : This type of compass has a magnetized needle suspended over a fixed card which has been marked off in a clockwise direction in 360 equal units(degrees). The cardinal compass points, north (0°), east (90°), south (180°) and west (270°) are always clearly marked. Intercardinal points (NE, SE, SW and NW) are usually shown plus divisions between these and the cardinal points, thus giving a total of sixteen compass directions. The needle moves freely to align itself north-south as the compass is turned.

Needle Compass

These compasses are generally available for student use in school science department.



3. Card Compass (Marine compass) : In this compass the needle is fixed while the compass card is mounted in fluid (is damped) and moves. Because the moving card absorbs much of the motion of a boat it is easier to read than a needle compass. The top of the compass is typically a hemispherical shape and may provide magnification of the readings on the card. The card is normally marked to show all readings from 0° through to 360°.

These compasses are usually mounted on the boat near to the steering apparatus in which case they are called the steering compass. Care must be taken not to allow nearby magnetic fields (e.g. metal apparatus) to interfere with the working of the compass.

Hand held models can be used to sight bearings of objects in the distance when fixing position.

Card Compass

4. Thumb Compass : This is a recently developed (1980's) modification of the baseplate compass where the baseplate is re-modelled to fit around the thumb so that the map and compass can be held together in one hand, leaving the other hand free. It is used chiefly for orienteering and rogaining.

Thumb Compass

5. Gyrocompass : This is an electric compass and as such is not affected by magnetic fields. Readings are true bearings and there is no need for adjustment for the Earth's magnetic field. These compasses are sophisticated, stable and very accurate. Large ocean-going vessels use a gyrocompass as their steering compass. Due to their size, weight and cost they are not usually found in use on smaller craft. Students may be able to see at a port for large ships.

6.Prismatic Compass : This compass has a glass prism sighting arrangement and a lid with a hairline for lining up the object to be sighted. The compass card rotates in the base and when it comes to rest the required bearing is read off, through the prisms. These are quite sophisticated hand compasses.

Prismatic Compass

Other types of Compass

Sun Compass : This is non-magnetic and uses the path of the sun as a reference line to indicate direction and works in reverse to a sundial.

Astro Compass : This is similar in principle to the sun compass but can be used with any celestial body. A frequent use is in the navigation of aircraft.

Earth-Inducer Compass: This compass indicates direction by measuring changes in the strength of the earth's magnetic field. They were once very popular in aircraft but as they are bulky and prone to error their use is now very limited.

Gyrosyn Compass : This is a composite instrument using a magnetic compass stabilised by a gyroscope. It is able to adjust quickly for changes in course and for this reason is widely used in aircraft.

Uses of Magnets

Magnets have many uses in our everyday life as well as in our homes. In our homes attractive forces between magnets keep our cabinet latches closed, as knife racks and most importantly used for displaying all your artwork on the fridge. However, the most important use of magnets in your home are the ones found in electric motors. Believe it or not its electromagnet and permanent magnets that help keep your blenders, vacuums, CD players and washing machines all running.

They are also termed "heads" when referring to your VCR. These "heads" record and read information on tapes covered with many tiny magnetic particles. The magnetic field of a recording head makes the magnetic particles on the tape form patterns that another type of head can read. The second head then transforms the magnetic patterns into an electric signal in which you can view your favorite episode.

In industry and business mostly electromagnetic powered devices will be found, such as cranes, cutters, fax machines, computers, etc. Powerful cranes (as the one below)
re commonly found in wrecking yards to help move scrap iron and steel from old cars as well as move metals for recycling.

It's also not uncommon nowadays to find electrified transportation. They as well rely on magnets in electric motors. Systems like this include: subways, trolleys, monorails, cable cars, escalators, elevators and moving sidewalks. They also add conveniences to our cars by aiding in electric windows, door lock, and windshield wipers. And lastly, electromagnets also produce radio waves in radar systems, an important navigation aid for ships and planes.

As the years continue to grow on us, so does technology. Magnets are also being used in medicine. There are certain type of magnets called bending magnets. They are powerful and are used to help control beams of atomic particles which is boosted into high speed devices called particle accelerators. A procedure most everyone has heard of, an MRI (Magnetic Renaissance Imaging) also relies on magnets.

Here, the person lies in between two magnets and the magnetic fields which cause some of the domains in the human body to align such as the heart, brain, spine and other internal organs. Physicians are then able to observe any magnetic fields generated by some of the organs.

Magnets in Living Things

Scientists have discovered that many animals, including pigeons, honey bees, salmon, tuna, dolphins and turtles are able to detect the earth's magnetic field and may use it to help find their way. Particles of magnetite have been found in the body tissues of these animals. They suspect the particles form part of a system that sense the geomagnetic field. Certain species of bacteria found in the water have also been found that use the geomagnetic field to find their preferred habitat. Each bacteria use the particles as tiny compass needles to guide them along the electromagnetic field.

Experiment 1

Objective

To study the different shapes and materials of magnet.

Items Required

Alnico (Aluminium-Nickel-Cobalt) material magnet

1.Bar magnet

2.Cylindrical magnet

3.U- shape magnet

4.Horse shoe magnet

Ceramic (Ferrite) material magnet

1.Ring magnet

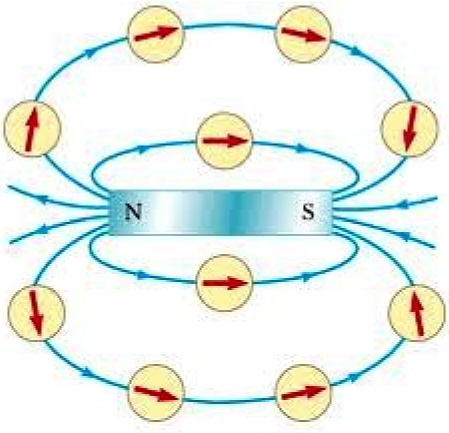
2.Disc shape magnet

Rare earth material magnet :

1.Disc shape NIB (Neodymium-Iron-Boron) magnet

Bar Magnet (Alnico) :

The lines of magnetic field from a bar magnet form closed loop. By convention, the field direction is taken to be outward from the North pole and in to the South pole outside of the magnet.



Magnetic Field Lines of a Bar Magnet

The magnetic field lines of a bar magnet can be traced out with the use of a compass. The needle of a compass is itself a permanent magnet and the north indicator of the compass is a magnetic north pole. The north pole of a magnetic needle will tend to

line up with the magnetic field, so a suspended compass needle will rotate until it lines up with the magnetic field. Unlike magnetic poles attract, so the north indicator of the compass will point toward the south pole of a magnet.

Bar magnet is used for educational purposes, various physics laboratory equipments. The design of large bar magnets for producing field at a distance is examined. One of the applications now being considered is the temporary degaussing of merchant ships.

Procedure

1.Take the bar magnet and compass from Magnetism Kit.

Bar Magnet

2. Place the compass near one end of the magnet. The needle of a compass is itself a permanent magnet and the north indicator of the compass is a magnetic north pole. One end of compass needle marked red shows magnetic north and the other end shows magnetic south. Magnetic north indicator is actually indicating geographic north and magnetic south is indicating geographic south of earth.

3.Now compass will deflect and then comes to rest. Unlike magnetic poles attract, so if the north indicator (red marked) of the compass point towards the pole of a magnet then it is south pole of the magnet and if south indicator (marked nothing) of the compass point towards the pole of magnet then it is north pole of the magnet.

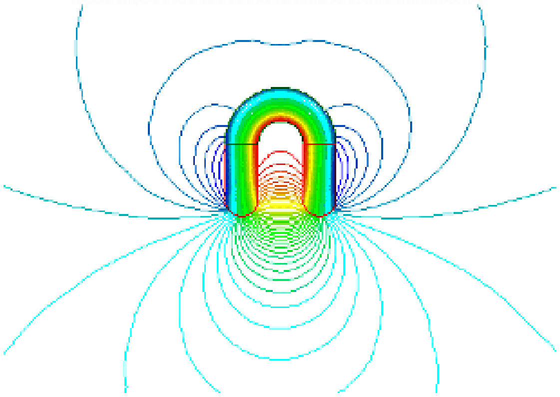
4.Bring the compass towards the other end of magnet. Now compass needle will point in opposite direction to that shown in step 3.

5.Now you can understand which pole is north and which is south.

Note : Pole marked with white dot is north and other one is south.

U-Shape Magnet (Alnico)

The lines of magnetic field from a U-shape magnet form closed loop. By convention, the field direction is taken to be outward from the North pole and in to the South pole outside of the magnet.

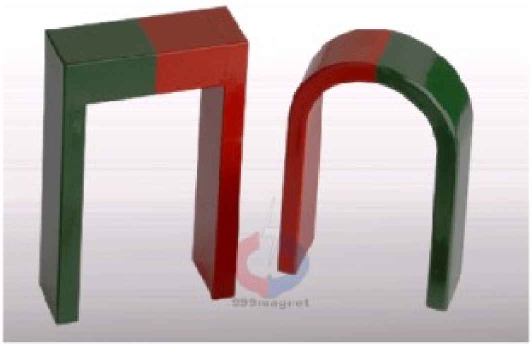


Magnetic Field Lines of a U-shape Magnet

These magnets are used in magnetic resonance imaging. The compact, open geometry U-shaped magnet of the present invention has a large imaging region within its bore where the magnetic field has a very high homogeneity. It is used in magnetic field- sensitive sensor. The NMR-Mouse is a palm-size NMR device which is built up from U-shaped magnet.

Procedure :

1. Take the U- Shape magnet and compass from Magnetism Kit.



U shape Magnet

2. Place the compass near one end of the magnet. The needle of a compass is itself a permanent magnet and the north indicator of the compass is a magnetic north pole. One end of compass needle marked red shows magnetic north and the other end shows magnetic south. Magnetic north indicator is actually indicating geographic north and magnetic south is indicating geographic south of earth.

3. Now compass will deflect and then comes to rest. Unlike magnetic poles attract, so if the north indicator (red marked)of the compass point towards the pole of a magnet it is south pole of the magnet and if south indicator (marked nothing) of the compass point towards the pole of magnet then it is north pole of the magnet.

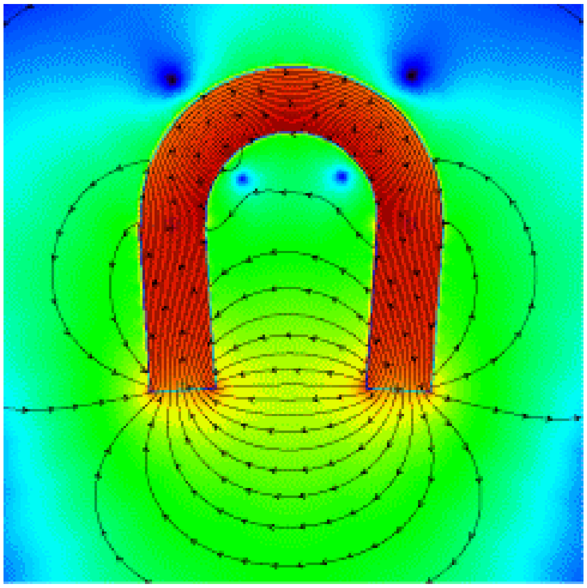
4.Bring the compass towards the other end of magnet. Now compass needle will point in opposite direction to that shown in step 3.

5.Now you can understand which pole is north and which is south.

Note : Pole marked with white dot is north and other one is south.

Horse-shoe Magnet (Alnico)

The lines of magnetic field from a horse shoe magnet form closed loop. By convention, the field direction is taken to be outward from the North Pole and in to the South Pole outside of the magnet. Horse-shoe is slightly different in shape from U shape. Its poles are slightly bent inside i.e. its north and south poles are near each other in comparison to U shape.

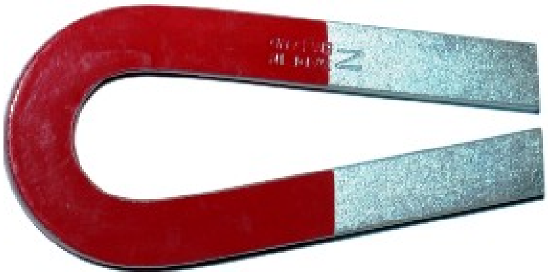


Magnetic Field Lines of a Horse-shoe Magnet

Horseshoe magnets were originally made to compensate for the very weak strength of bar magnets. By making both ends of the magnet point in the same direction, the lifting strength of the magnet is doubled. They have largely been replaced by stronger magnets for this purpose but they are still handy for use with paper clips, etc. in physics demonstrations.

Procedure

1. Take the horse shoe magnet and compass from Magnetism Kit.



Horse-shoe Magnet

2. Place the compass near one end of the magnet. The needle of a compass is itself a permanent magnet and the north indicator of the compass is a magnetic north pole. One end of compass needle marked red shows magnetic north and the other end shows magnetic south. Magnetic north indicator is actually indicating geographic north and magnetic south is indicating geographic south of earth.

3.Now compass will deflect and then comes to rest. Unlike magnetic poles attract, so if the north indicator (red marked) of the compass point towards the pole of a magnet then it is south pole of the magnet and if south indicator (marked nothing) of the compass point towards the pole of magnet then it is north pole of the magnet.

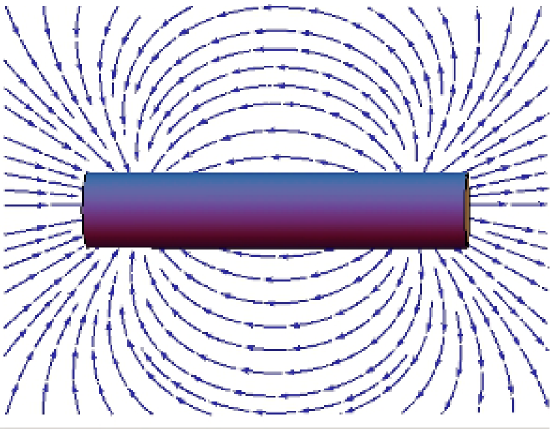
4.Bring the compass towards the other end of magnet. Now compass needle will point in opposite direction to that shown in step 3.

5.Now you can understand which pole is north and which is south.

Note : Pole marked with white dot is north and other one is south.

Cylindrical Shape Magnet (Alnico)

The lines of magnetic field from a cylindrical magnet form closed loop. By convention, the field direction is taken to be outward from the North Pole and in to the South Pole outside of the magnet.



Magnetic Field Lines of a Cylindrical Magnet

Small size cylindrical shape magnets are used in magnet sensors and proximity sensors. Large size cylindrical shape magnets are used for industrial purposes.

Procedure

1. Take the cylindrical shape magnet and compass from Magnetism Kit.

Cylindrical Magnet

2. Place the compass near one end of the magnet. The needle of a compass is itself a permanent magnet and the north indicator of the compass is a magnetic north pole. One end of compass needle marked red shows magnetic north and the other end shows magnetic south. Magnetic north indicator is actually indicating geographic north and magnetic south is indicating geographic south of earth.
3. Now compass will deflect and then comes to rest. Unlike magnetic poles attract, so if the north indicator (red marked)of the compass point towards the pole of a magnet then it is south pole and if south indicator (marked nothing) of the compass point towards the pole of magnet then it is north pole of the magnet.

4.Bring the compass towards the other end of magnet. Now compass needle will point in opposite direction to that shown in step 3.

5.Now you can understand which pole is north and which is south.

Note: Pole marked with white dot is north and other one is south.

Ring Magnet (ceramic or ferrite):

The lines of magnetic field from a ring magnet form closed loop. By convention, the field direction is taken to be outward from the North Pole and in to the South Pole outside of the magnet.

Magnetic Field Lines of a Ring Magnet

Ring magnets are available in a variety of materials including ceramic, rare earth and flexible materials. Ring magnets normally are specified as having a number of poles. A four-pole ring magnet contains two north and two south oriented poles (NSNS).

Commercial ring magnets have a wide range of applications in magnetic sensing applications like hall-effect sensors, speed and direction sensor. It is also used in DC permanent magnet motors, DC brushless motors, Magnetic resonance imaging, loud speaker, food processing industries, separators that is it separates ferrous material from non-ferrous materials, in magnetic assemblies meant for lifting, holding, retrieving, and separating at a large scale. The Polar Anisotropic Ferrite Ring Magnets are the magnets with multi-poles in ring shape. They have become the key component of stepping motors which are widely used in computer peripheral and consumer electronics, such as CD-ROM, Scanner, Printer and Digital-Camera, etc.

Procedure

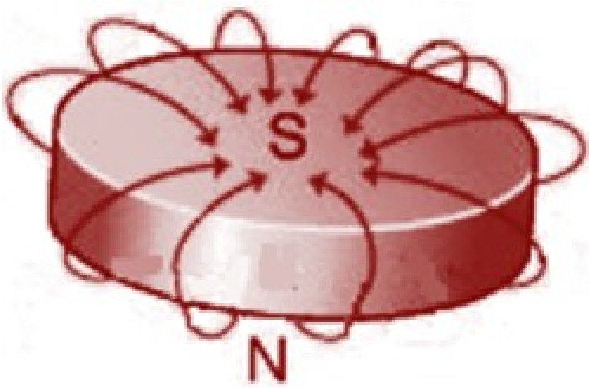
1. Take the ring shape magnet and compass from Magnetism Kit.

Ring Magnet

2. Place the compass near one ring shaped side of magnet. The needle of a compass is itself a permanent magnet and the north indicator of the compass is a magnetic north pole. One end of compass needle marked red shows magnetic north and the other end shows magnetic south. Magnetic north indicator is actually indicating geographic north and magnetic south is indicating geographic south of earth.
3. Now compass will deflect and then comes to rest. Unlike magnetic poles attract, so if the north indicator (red marked)of the compass point towards the pole of a magnet then it is south pole of the magnet and if south indicator (marked nothing) of the compass point towards the pole of magnet then it is north pole of the magnet.
4. Bring the compass towards the other side of magnet. Now compass needle will point in opposite direction to that shown in step 3.
5. Now you can understand which pole is north and which is south.

Disc shape magnet (ceramic or ferrite and NIB) :

The lines of magnetic field from a disc shape magnet form closed loop. By convention, the field direction is taken to be outward from the North Pole and in to the South Pole outside of the magnet.



Magnetic Field Lines of a Disc shape Magnet

Disc shape (Ceramic) magnets have several applications like Craft projects, badge holders, latches, sensor applications, display boards, science projects, toys, magnetic jewelry, games and many others.

Neodymium magnets are used for many purposes. They are used in industries, commercially and can even come handy around the house. Neodymium magnets are also used in the Medicine and Health fields for a large number of purposes.

Industrial Uses of Neodymium Magnets

Neodymium magnets are often used in machines made for the health industry. They are also used for magnetization, to make magnetic separators, magnetic filters and for magnetic ionization.

The security industry uses them for alarms and switches, security systems. Neodymium magnets are also commonly used in the hard drives of computers, in telephonic applications, in television and video applications, for chip detectors.

Neodymium magnets are also very popular in the manufacturing of generators. Generally the stronger the magnet the better the generator.

Medicine & Health Uses of Neodymium Magnets:

- Neodymium magnets are very popularly used for magnetic therapy to help alleviate the symptoms and relieve pain caused by health problems like arthritis. They have high healing ability and often called healing magnets as well.
- NASA uses Neodymium magnets for the purpose of maintaining muscle tone in astronauts during space flights.
- Neodymium magnets are used in MRI scanning machines.

Educational Purposes of Neodymium Magnets:

Neodymium magnets are very popular with students of advanced Physics for experimentation and research purposes. Their small size but high strength makes them easily stored and carried.

Using Neodymium Magnets as Handy Tools Around The House:

Neodymium magnets in really small sizes make great toys not only for kids but adults as well. The possibilities are endless and the fun just doesn’t end.

Neodymium magnets are often used as oil filters to separate any iron fillings or other metal chips from the oil.

Neodymium magnets also work great as metal detectors – whether you want to use them as stud finders to find nails in the wall, search for nails under your flooring or just find the nail you dropped under your bed somewhere.

You can even use Neodymium magnets to hold things in place. You can hold down tarps to cover your machinery and cars. You can make a tool belt for yourself using Neodymium magnets creatively.

You can also use a pair of Neodymium magnets to make yourself clip on earrings, jewelry clasps and hold name tags in place on your clothing without having to stitch them on.

Thus, Neodymium magnets have a wide variety of uses, they are very popular.

Other applications of rare-earth magnets include

Diamagnetic levitation experimentation, the study of magnetic field dynamics and superconductor levitation.

Launched roller coaster technology found on roller coaster and other thrill rides.

Procedure :

1. Take the disc shape magnet and compass from Magnetism Kit.

Neodymium-Iron-Boron (NIB) **Ceramic or Ferrite**

Disc Shape Magnets

2. Place the compass near one side of magnet. The needle of a compass is itself a permanent magnet and the north indicator of the compass is a magnetic north pole. One end of compass needle marked red shows magnetic north and the other end shows magnetic south. Magnetic north indicator is actually indicating geographic north and magnetic south is indicating geographic south of earth.

3. Now compass will deflect and then comes to rest. Unlike magnetic poles attract, so if the north indicator (red marked) of the compass point towards the pole of a magnet then it is south pole of the magnet and if south indicator (marked nothing) of the compass point towards the pole of magnet then it is north pole of the magnet.

4. Bring the compass towards the other side of magnet. Now compass needle will point in opposite direction to that shown in step 3.

5. Now you can understand which pole is north and which is south.

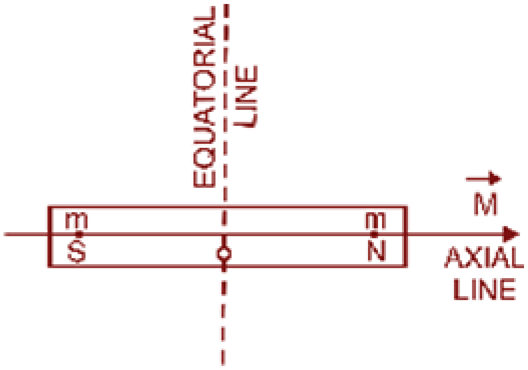
Combined Magnetic Field of the Earth and a Bar Magnet

Terms Related With A Bar Magnet (Magnetic Dipole) :

1.North seeking and south seeking ends : For a freely suspended magnet, the end pointing towards north, is called north seeking end and the end pointing towards south, is called south seeking end.

2. Poles : Center of attraction, near the ends of a magnet, are called poles of the magnet.

The pole near the north seeking end is called north (N) pole. The pole near the south seeking end, is called south (S) poles .



Terms related with a Bar Magnet

3. Magnetic length: The distance between the two poles of a magnet, is called the magnetic length of the magnet. It is represented by L or 2l. It is about 5/6 or 7/8 of geometrical length (end to end).

4. Pole strength: The number of unneutralized unit poles present on each pole of the magnet is called Strength of the magnet. It is represented by m.

5. Magnetic moment: The product of the magnetic length and the pole strength of a magnet is called the magnetic moment of the magnet. Its symbol is *M* and

$$M = mL = 2ml.$$

It is a vector quantity represented by $\vec{M}$. It acts from North Pole outward

6.Axial line: The straight line passing through the poles of a magnet is called the axial line of the magnet.

7.Center: A point on the axial line in the middle of the poles is called the center of the magnet. It is shown by O in above Fig.

8. Equatorial line: The straight line perpendicular to the axial line at the center of the magnet is called equatorial line of the magnet. Every point on this line is at equal distance from both the poles of the magnet.

9.Magnetic meridian: A plane perpendicular to magnet surface on its axial line, is called magnetic meridian of the magnet.

Some Facts About A Magnet

1.Both poles of a magnet are equally strong. For this reason, a magnet is also called a magnetic dipole.

2.Like poles repel each other, unlike poles attract each other.

3.Repulsion is the sure test of magnetism.

4.A single magnetic pole does not exist.

Coulomb's Law of Force Between Magnetic Poles:

Statement : The force of attraction or repulsion between two magnetic poles is directly proportional to the product of the strength of the two poles and inversely proportional to the square of the distance between them.

The force is mutual and acts along the line joining the poles.

Expression: If two magnetic poles of strength $+m_1$, and $+m_2$ be kept at distance r apart, the repulsive force F between them is given by

$$F = K\frac{m_1 m_2}{r^2}$$

where k is constant of proportionality. Its value depends upon the medium and system of units chosen.

For medium as air, k = 1 in C.G.S. units and $\frac{\mu_0}{4\pi}$ in S.I. unit. [μ_0 is permeability of free space, its value being 4π□x 10^{-7} weber/amp. metre (Wb A^{-1} m^{-1})].

Unit Magnetic Pole

Force between two magnetic poles in any medium is given by

$$F = \frac{\mu_0}{4\pi}\mu\frac{m_1 m_2}{r^2} \text{ (S.I. Units)}$$

where μ is permeability of the medium.

If $m_1 = m_2 = \pm 1$ (+ for North Pole, - for South Pole)

$\mu = 1$ (for air, strictly vacuum)

r = 1 meter

Then, $F = \frac{\mu_0}{4\pi} = 10^{-7}$ N

Hence, a unit pole is that which when placed in air (strictly in vacuum) at a distance of 1 meter from a similar pole of same strength, will repel it and will be repelled by it, with a force of 10^{-7} Newton.

Magnetic Field

The space around a single magnetic pole or a magnetic dipole in which its influence is experienced by another single magnetic pole or magnetic dipole is called the magnetic field of the first single magnetic pole or magnetic dipole.

Magnetic Field Intensity

1. Definition : Magnetic field intensity at a point in the magnetic field of a single magnetic pole is defined (or measured) as the force experienced by a unit north pole (test pole) placed at that point (provided that the presence of the test pole does not effect the original field). It is represented by the symbol B. It is also called magnetic Flux density at that point.

***2.*Expression :** For a fixed pole of strength m, $m_1 = m$, m_2 (test pole) = 1 and F=B.

From expression, $$F = k\frac{m_1 m_2}{r^2}$$

We have, $$B = \frac{m}{r^2} \text{ (C.G.S. units)}$$

$$= \frac{\mu_0}{4\pi}\frac{m}{r^2} \text{ (S.I. units)}$$

3.Unit *:* S.I. unit of B is tesla (T).

One tesla is magnetic field intensity at a point, if a force of one newton acts on a unit north pole placed there.

(1 tesla = 10^4 gausses =10^7 oersteds)

4. **Direction *:*** B is a vector quantity (because it is a force) represented by $\vec{B}$. It acts in direction of force on a unit north pole. Hence it acts away from a north pole and towards a south pole.

Uniform Magnetic Field

Magnetic field in a space (region) is uniform, if same force acts in same direction on a unit north pole kept at any point in that space (region).

Magnetic Field Intensity Due to A Bar Magnet

Introduction : A bar magnet (magnetic dipole) has a north (positive) and a south (negative) pole of same strength separated by a distance equal to the magnetic length of the magnet. At any point, the magnetic field intensity is the vector resultant of the magnetic field intensities of the two single magnetic poles.

As the orientation of these two magnetic poles change for each point in the field, the resultant magnetic field intensity differs both in magnitude and direction from point to point.

Two special cases arise

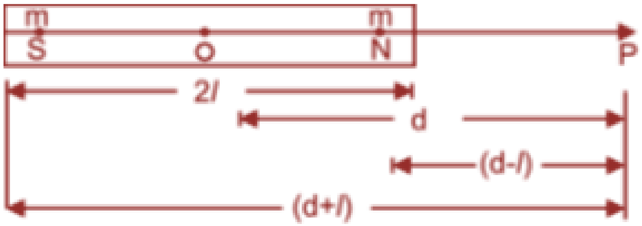
i.When point lies on the axial line of the magnet.

ii. When point lies on the equatorial line of the magnet.

We shall calculate the magnetic field intensity for these two special cases.

Magnetic Field Intensity due to a Bar Magnet at a point on its Axial Line

1. **Introduction :** Let a bar magnet have, pole strength m, magnetic length 2*l* and magnetic moment M = 2m*l*



Magnetic field intensity due to a magnet at a point on its axial line

Let P be any point on its axial line at distance d from its centre 0.

2. **Calculation :** (In C.G.S. units) Magnetic field intensity at P due to N-pole,

$$= \frac{m}{(NP)^2} = \frac{m}{(d-l)^2} \text{ along NP}$$

Magnetic field intensity at P due to S-pole,

$$= \frac{m}{(SP)^2} = \frac{m}{(d+l)^2} \text{ along PS}$$

Resultant field intensity at P

$$F_{Axial} = \frac{m}{(d-l)^2} - \frac{m}{(d+l)^2} \text{ along NP}$$

$$= \frac{m\left[(d+l)^2-(d-l)^2\right]}{\left(d^2-l^2\right)^2} = \frac{m.4d.l}{(d^2-l^2)^2} = \frac{2.2ml.d}{(d^2-l^2)^2}$$

Or

$$F_A = \frac{2Md}{(d^2-l^2)^2}$$

For a Short magnet,

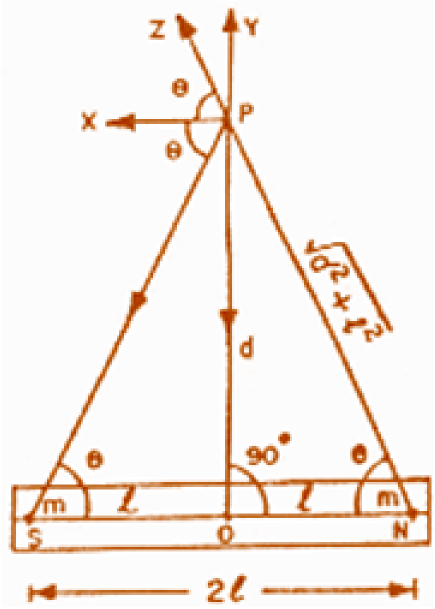
$$d >>> l,\ (d^2 - l^2)^2 \rightarrow d^4$$

Then

Magnetic Field Intensity due to a Bar Magnet at a point on its Equatorial Line

1. **Introduction :** Let a bar magnet have pole strength m, magnetic length $2l$ and magnetic moment $M = 2ml$.

$$F_A = \frac{2M}{d^3} \text{ along NP}$$



Magnetic field intensity due to a bar magnet at a point on its equatorial line

Let P be any point on its equatorial line at distance d from its centre O (Fig. 25).

2.Calculation : (In C.G.S. units) Magnetic field intensity at P due to N-pole =

$$\frac{m}{(NP)^2} = \frac{m}{(d^2 - l^2)}$$

(Along NPZ)

Magnetic field intensity at P due to S-pole =

$$\frac{m}{(NP)^2} = \frac{m}{(d^2 + l^2)}$$

Drawing PX parallel to NS

Then, $< ZPX =< SPX =< PNS =< PSN = \theta\ (say)$

Components of intensity (force) along PZ are

i. $\frac{m}{(d^2+l^2)}$ sinθ along PY

ii. $\frac{m}{(d^2+l^2)}$ Cos θ along PX

Components of intensity (force) along PS are

i. $\frac{m}{(d^2+l^2)}$ sinθ along PO

ii. $\frac{m}{(d^2+l^2)}$ Cos θ along PX

The two sin components get cancelled

The two cos components get added

i. $F_{Equatorial} = 2\frac{m}{(d^2+l^2)}$ Cos θ along PX

$$F_E = \frac{2m}{(d^2+l^2)} \frac{l}{(d^2+l^2)^{1/2}} \left[\cos\theta = \frac{1}{\sqrt{(d^2+l^2)}}\right]$$

Resultant field intensity at P, or

$$F_E = \frac{M}{(d^2 + l^2)^{3/2}}$$

along PX (|| to NS)

For a short magnet, d $>>> l, (d^2 + l^2)^{3/2} \rightarrow d^3$

Then

$$\mathrm{F_E} = \frac{M}{d^3} \text{ along PX}$$

Note . For a short magnet , for same d ,FA = 2FE.

Superposition of Magnetic Fields of Magnet and the Earth

Since earth behaves as a magnet, it has its own magnetic field (due to its horizontal component), which is uniform over a wide region. When a magnet is placed at a point, its magnetic field gets superposed on that of the earth. This modifies the intensity of the magnetic field of the magnet. Resultant magnetic field intensity round a magnet will change with the orientation of the magnet. When this field is mapped, different types of field patterns are obtained.

Neutral Point

The horizontal component of earth's magnetic field has same magnitude and same direction over a large region. Magnetic field of the magnet has different magnitude and different direction at different points. At some point, in the region of the magnetic field of the magnet, the two magnetic fields become equal and opposite. It makes resultant magnetic field intensity zero at that point. Such a point is called neutral point.

Hence neutral point is that point, in the region of the magnetic field of the magnet, at which the magnetic field intensities of the earth and the magnet have equal magnitudes and opposite directions. It is represented by N in diagrams.

The resultant magnetic field intensity is zero at a neutral point.

Two neutral points, N_1 and N_2, exists symmetrically with respect to the axial line of the magnet.

Location of Neutral Points

a.Magnet placed with its North-pole pointing towards geographical North pole of the earth :

In this orientation of the magnet, the mapped field pattern comes as shown in Fig.Fields are opposite in the region along the equatorial line. Hence neutral points N_1 and N_2 lie on the equatorial line.

If H represents the horizontal component of earth's magnetic field and B represents the magnetic field intensity of the magnet, then at each neutral point

$$B = H.$$

But for a point on the equatorial line,

$$B = \frac{M}{(d^2 + l^2)^{3/2}}$$

Hence,

$$\frac{M}{(d^2 + l^2)^{3/2}} = H$$

Or $M = H(d^2 + l^2)^{3/2}$ (C.G.S.unit)

This can be calculated Further $M = 2ml$ or $m = \frac{M}{2l}$

b. Magnet placed with its North-pole pointing towards geographical South pole of the earth

In this orientation of the magnet, the mapped field pattern comes as shown in Fig. 29. Fields are opposite in the region along the axial line. Hence neutral points N_1 and N_2 lie in the axial line.

As before B = H.

But for a point on the axial line,

$$B = \frac{2Md}{(d^2 - l^2)^2}$$

Hence,

$$H = \frac{2Md}{(d^2 - l^2)^2}$$

Or

$$M = \frac{H\left(d^2 - l^2\right)^2}{2d} \text{ (C.G.S. unit)}$$

This can be calculated further

$$M = 2ml \text{ or } m = \frac{M}{2l}$$

Rule for Location of Neutral Points

When North-pole of the magnet points towards geographical South-pole of the earth, the two neutral points come symmetrically on the axial line. (Case b)

When North-pole of the magnet points towards geographical North-pole of the earth, the two neutral points come symmetrically on the equational line. (Case a)

From above we find that when the axial line of the magnet is rotated by 180°, the line of neutral points turns by 90° (half the angle) in same sense.

Hence, with North-pole of the magnet towards geographical West, the neutral points will be on North-East and South-West line. With North-pole of the magnet towards geographical East, the neutral points will lie on North-West and South-East line.

Neutral points with A Vertical Magnet

When magnet is kept vertical on the paper, only one pole lies on the paper. The magnetic field of the magnet on the paper will be due to one pole only. Hence only one neutral point will be obtained. It will lie on North-South line. With North-pole of the magnet on the paper, the single neutral point will be towards South. With South- pole of the magnet on the paper, the single neutral point will be towards North.

Magnetic Lines of Force

1. **Definition :** A magnetic line of force is a line, straight or curved, in the magnetic field of a magnetic pole or magnetic dipole, such that the tangent at any point of this line gives the direction of the magnetic field at that point.

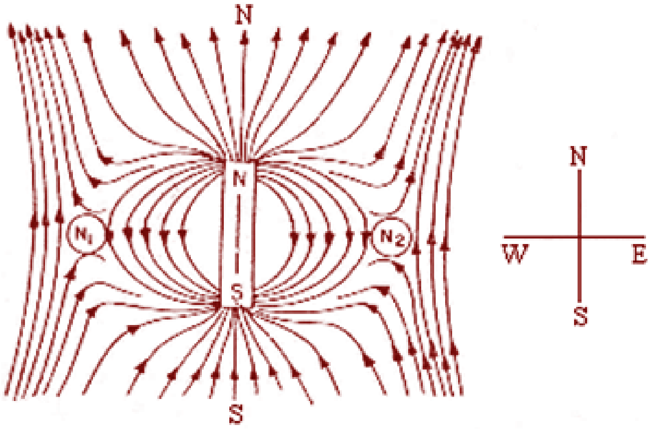
A free unit north pole (test pole) will move along the magnetic line of force in direction of the field.

2.Direction : Since a free unit north pole will move away from a north pole and towards a south pole, its direction is from a north towards a south pole.

3.Properties : Following are the properties of magnetic lines of force:

- They are always nearly normal to the surface of a ferromagnetic substance at every point.
- They start from a north (positive) pole and end at a south (negative) pole.
- Two lines of force do not intersect each other. If they intersect at a point, there will be two directions of field, at that point. Since it is impossible, hence they do not intersect.
- They tend to contract longitudinally (longitudinal contraction).
- They tend to expand laterally (lateral repulsion).
- The number of magnetic lines of force passing normally per unit area about a point, gives the intensity of the magnetic field at that point. (It is for this reason that the magnetic field intensity is called magnetic flux density).

4.Importance : The distribution of lines of force round a magnetic pole or magnetic dipole, gives the mapping of the magnetic field in that region



Experiment 2

Objective

To plot the combined magnetic field of the earth and a bar magnet placed along the magnetic meridian with its north-pole pointing towards geographical north of the earth. To locate the neutral points and calculate the magnetic moment and the pole strength of the magnet. Given that H = 0.32 oersted.

Items required

1.Bar Magnet

2.Small magnetic compass

Following things you have to arrange in your laboratory

3.Card board or wooden drawing board

4.Sheet of white paper

5.4 brass drawing pins or gum

6.Knitting needle

7.Half meter scale

8.Sharp pointed pencil

9.Piece of chalk

North pole of magnet towards geographical north of earth

Theory (Formulae Used)

1. Magnetic moment of the bar magnet is given by,

$$M = H(d^2 + l^2)^{3/2} \text{ (C.G.S.unit)}$$

2. Pole Strength of the magnet is given by,

$$m = \frac{M}{2l}$$

where H= Horizontal component of earth's magnetic field,

d = Mean distance of a neutral point from the centre of the magnet, and

$2l$ = Magnetic length of the bar magnet.

Procedure

1.Choose a wooden table whose boards are fixed with wooden nails (not usual iron nails).

(**Note:** Remove all the magnetic substances, magnet from the table. Also, remove your wrist watch.)

2. Take a card board or drawing board and fix the white paper sheet on it with the help of brass pins or gum.

3. Draw (with sharp pencil) perpendicular lines parallel to length and breadth of the paper in the middle (the lines cut at the centre of the paper).

4. Place the small magnetic compass needle with its center at the center of the paper.

5. Rotate the drawing board and go on tapping the needle so that it remains free.

6. Rotate till the magnetic needle becomes parallel to one of the perpendicular lines. (This line is along magnetic north-south of the earth).

7. Mark this line as N-S line. Write N towards geographical north and S towards geographical south.

8. Draw the boundary of the drawing board on the table with a piece of chalk. See that the drawing board maintains this boundary during experiment.

9. Now remove the compass and place the bar magnet symmetrically over the N-S line in the middle of the paper with its north pole towards geographical north of earth.

10. Mark the boundary of the magnet with sharp pencil.

Rough Location of Neutral Points

11. Place the compass needle in the middle of the magnet on the line perpendicular to axial line. It will act as equatorial line of the magnet. The north pole of the needle will be towards south and needle will be steady.

12. Move the compass needle on the line away from the magnet. The needle will become shaky.

13. At one position on the equatorial line, needle becomes along the line (east- west). This is the rough location of the neutral point. Draw a circle round the compass needle.

14. Repeat steps 11-13 by keeping the needle on the other side of the magnet.

To draw lines of force due to magnetic field of magnet

15. Mark a dot with pencil near the north pole of the magnet and place the compass needle in such a way that its S-pole lies just against the dot. When the needle comes to rest, mark a dot just opposite to the other end of the needle.

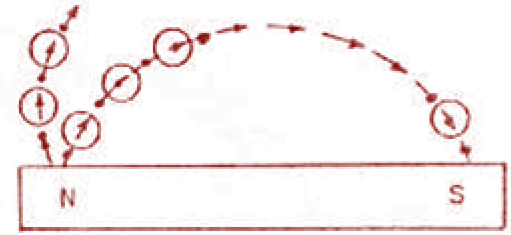
16. Lift the compass needle and place it such that its south pole lies just opposite to the dot which was marked near its N-pole and again mark another dot in the same manner as done earlier.

17. Repeat this process, moving the compass needle forward till the south pole of the bar magnet is reached.

18. Join all these marked points by drawing a free hand curve. This curve gives line of force.

19. Mark an arrow indicating the direction of this line of force, starting from north pole and ending at the south pole of the magnet.

20. Similarly, plot sufficient number of magnetic lines of force on both sides of the magnet, starting from points close to the N-pole of the magnet.



Drawing Lines of force

To draw lines of force due to earth's magnetic field

21. Mark dots near the west corner of the white sheet of paper and taking each one of them as the starting point, draw the lines of force in a similar way as explained above in Steps 15 to18. These lines of force will give rise to a curvilinear quadrilateral in the neutral region.

22. Draw more magnetic lines of force near the neutral point region and narrow down this area as much as possible. (The space containing no lines of force is the neutral region. The neutral point N_1 lies at its center).

23. Similarly, locate the second neutral point N_2 on other (east) side of the magnet on its equatorial line.

To test the neutral point

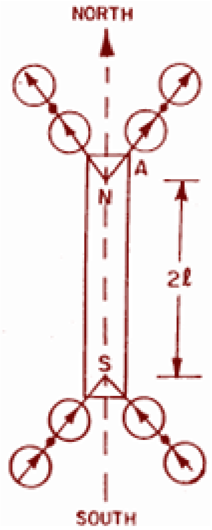
24. Place the compass needle with its center lying at the neutral point.

25. Take a knitting needle and bring one end of it near the magnetic compass. It will attract the compass needle and the position of the magnetic needle will be disturbed.

26. Remove the knitting needle gently away from the compass without disturbing it. If the neutral point has been correctly located, the compass needle will remain pointing in the same direction. (Similarly, it can be made to point in any direction. This is because the resultant magnetic field at the neutral point is zero).

To find the magnetic length

27. Produce the lines of force traced out at each of the corners of the magnet to meet inside the boundary of the magnet at points N and S as shown in Figure below . These are the actual positions of magnetic poles.



Determination of Magnetic Length

28. Measure the distance between N and S poles. It is the magnetic length $2l$ of the magnet.

29. Measure the distance of the neutral points N1 and N2 from the center of the magnet.

30. Record your observations as given below.

Observations :

1. Distance of neutral point N1 from the center of the

magnet, d1 =…….cm.

2. Distance of neutral point N2 from the center of the magnet,

d2 =…….cm.

3. Distance between neutral points N1and N2 , d1 + d2 =………cm.

4. Mean distance, $d=\frac{d_1+d_2}{2}$

5. Magnetic length of the bar magnet,

$2l$ =………cm

l = ……...cm.

6. Horizontal component of earth's magnetic field, H =0.32 oersted (given).

Calculations

1. Magnetic moment of the bar magnet,

$$M = H(d^2 + l^2)^{3/2} = 0.32\ (d^2 + l^2)^{3/2}$$

= ……. C.G.S. units

2. Pole strength, $m = \frac{M}{2l}$ (C.G.S. unit)

Result

1. Magnetic moment of the given bar magnet

M =………C.G.S units.

2. Pole strength of the given bar magnet,

m =………C.G.S units.

Precautions

1. There should be no iron nail in the drawing board or in the table.

2. There should be no magnet or magnetic substance on the table near the cardboard or drawing board.

3. Boundary of the board and magnet should be marked. This will be help in keeping the magnet at the same position in case it is disturbed.

4. The magnetic compass needle should be frictionless and small in size, so that needle rotates freely.

5. The compass should be gently tapped each time.

6. Points should be marked with thin pointed pencil.

7. Marked points should be joined by smooth curve.

8. The direction of the magnetic lines of force should be indicated by arrow heads.

Sources of Error

1. Polarity of magnet or compass needle may be wrong.

2. Some magnetic substance may be hidden in table or board.

Experiment 3

Objective

To plot the combined magnetic field of the earth and a bar magnet placed along the magnetic meridian with its north-pole pointing towards geographical south of the earth. To locate the neutral points and calculate the magnetic moment and the pole strength of the magnet. Given that H = 0.32 oersted.

Items required

1.Bar Magnet

2.Small magnetic compass

Following things you have to arrange in your laboratory

3.Card board or wooden drawing board

4.Sheet of white paper

5.4 brass drawing pins or gum

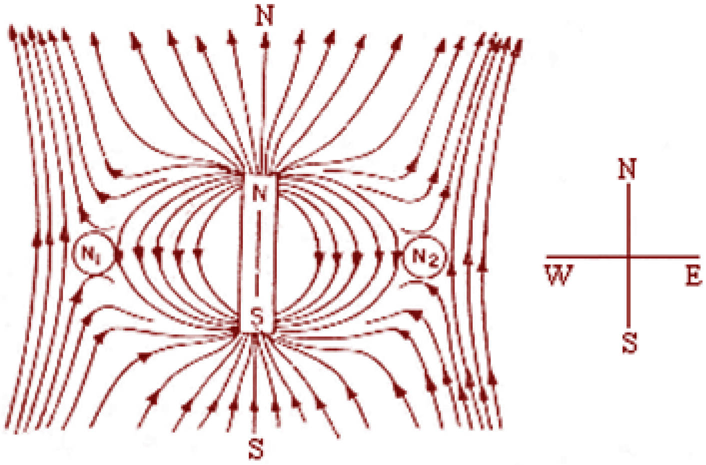
6.Knitting needle

7.Half meter scale

8.Sharp pointed pencil

9.Piece of chalk

Diagram



North Pole of magnet towards geographical south of earth

Theory

1. Magnetic moment of the given magnet is given by

$$M = \frac{H\left[d^2 - l^2\right]}{2d} \left(\text{In C.G.S. units}\right)$$

2. Pole strength of the magnet is given by,

$$m = \frac{M}{2l}$$

Where H = Horizontal component of earth's magnetic field,

d = Mean distance of a neutral point from the center of the magnet, and

$2l$ = Magnetic length of the bar magnet.

Procedure

1. Choose a wooden table whose boards are fixed with wooden nails (not usual iron nails).

(**Note:** Remove all the magnetic substances, magnet from the table. Also, remove your wrist watch.)

2. Take a card board or drawing board and fix the white paper sheet on it with the help of brass pins or gum.

3. Draw (with sharp pencil) perpendicular lines parallel to length and breadth of the paper in the middle (the lines cut at the centre of the paper).

4. Place the small magnetic compass needle with its center at the center of the paper.

5. Rotate the drawing board and go on tapping the needle so that it remains free.

6. Rotate till the magnetic needle becomes parallel to one of the perpendicular lines (This line is along magnetic north-south of the earth).

7. Mark this line as N-S line. Write N towards geographical north and S towards geographical south.

8. Draw the boundary of the drawing board on the table with a piece of chalk. See that the drawing board maintains this boundary during experiment.

9. Now remove the compass and place the bar magnet symmetrically over the N-S line in the middle of the paper with its north pole towards geographical south of the earth.

10. Mark the boundary of the magnet with sharp pencil.

Rough Location of Neutral Points

11. Place the compass needle at one end of the magnet on the axial line. It will act as equatorial line of the magnet. The north pole of the needle will be towards south and needle will be steady.

12. Move the compass needle on the line away from the magnet. The needle will become shaky.

13. At one position on the axial line, needle becomes perpendicular to the line(east- west).

14. Repeat steps 11-13 by keeping the needle at the other end of the magnet.

To draw lines of force due to magnetic field of magnet

15. Mark a dot with pencil near the north pole of the magnet and place the compass needle in such a way that its S-pole lies just against the dot. When the needle comes to rest, mark a dot just opposite to the other end of the needle.

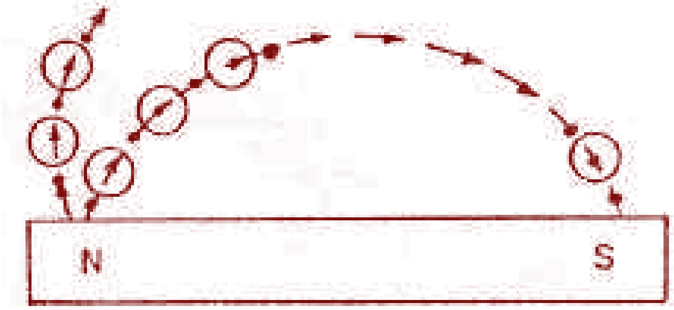
16. Lift the compass needle and place it such that its south pole lies just opposite to the dot which was marked near its N-pole and again mark another dot in the same manner as done earlier.

17. Repeat this process, moving the compass needle forward till the south pole of the bar magnet is reached.

18. Join all these marked points by drawing a free hand curve. This curve gives line of force.

19. Mark an arrow indicating the direction of this line of force, starting from north pole and ending at the south pole of the magnet.

20. Similarly, plot sufficient number of magnetic lines of force on both sides of the magnet, starting from points close to the N-pole of the magnet.



Drawing Lines of force

To draw lines of force due to earth's magnetic field

21. Mark dots near the west corner of the white sheet of paper and taking each one of them as the starting point, draw the lines of force in a similar way as explained above in Steps 15 to18. These lines of force will give rise to a curvilinear quadrilateral in the neutral region.

22. Draw more magnetic lines of force near the neutral point region and narrow down this area as much as possible. (The space containing no lines of force is the neutral region. The neutral point N_1 lies at its center).

23. Similarly locate the second neutral point N_2 on other (N-pole) end of the magnet on its axial line.

To test the neutral point

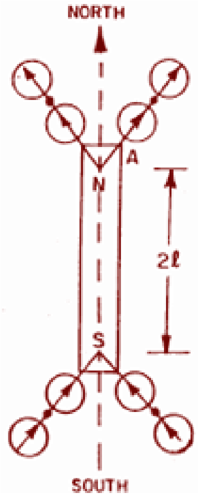
24. Place the compass needle with its center lying at the neutral point.

25. Take a knitting needle and bring one end of it near the magnetic compass. It will attract the compass needle and the position of the magnetic needle will be disturbed.

26. Remove the knitting needle away from the compass without disturbing it. If the neutral point has been correctly located, the compass needle will remain pointing in the same direction. (Similarly, it can be made to point in any direction. This is because the resultant magnetic field at the neutral point is zero).

To find the magnetic length

27. Produce the lines of force traced out at each of the corners of the magnet to meet inside the boundary of the magnet at points N and S as shown in below figure. These are the actual positions of magnetic poles.



Determination of Magnetic Length

28. Measure the distance between N and S poles. It is the magnetic length $2l$ of the magnet.

29. Measure the distance of the neutral points N_1 and N_2 from the center of the magnet.

30. Record your observations as given below.

Observations

1. Distance of neutral point N1 from the center of the

   magnet, d1 =…….cm.

2. Distance of neutral point N2 from the center of the magnet,

   d2 =…….cm.

3. Distance between neutral points N1and N2 ,

   d1 + d2=………cm.

4. Mean distance, d = $\frac{d_1+d_2}{2}$ =……cm

5. Magnetic length of the bar magnet,

   $2l$ =………cm

   l = ………cm.

6. Horizontal component of earth's magnetic field, H =0.32 oersted (given).

Calculations

1. Magnetic moment of the bar magnet,

2. $M = \frac{\mathrm{H}\left(d^2+l^2\right)^2}{2d} = \frac{0.32\left(d^2+l^2\right)^2}{2d}$

a. = ……… C.G.S. units

3. Pole strength,

$$m = \frac{M}{2l}$$

= ……. C.G.S. units

Result

1. Magnetic moment of the given bar magnet,

   M =………C.G.S units.

2. Pole strength of the given bar magnet,

   m =………C.G.S units.

Precautions

1. There should be no iron nail in the drawing board or in the table.
2. There should be no magnet or magnetic substance on the table near the cardboard or drawing board.
3. Boundary of the board and magnet should be marked. This will be help in keeping the magnet at the same position in case it is disturbed.
4. The magnetic compass needle should be frictionless and small in size,

so that needle rotates freely.

5. The compass should be gently tapped each time.

6. Points should be marked with thin pointed pencil.

7. Marked points should be joined by smooth curve.

8. The direction of the magnetic lines of force should be indicated by arrow heads.

Sources of Error

1. Polarity of magnet or compass needle may be wrong.

2. Some magnetic substance may be hidden in table or board.

Experiment 4

Objective

To observe the magnetic field lines of bar magnet on Magnetic Field Demonstrator.

Items Required

1.Magnetic field demonstrator

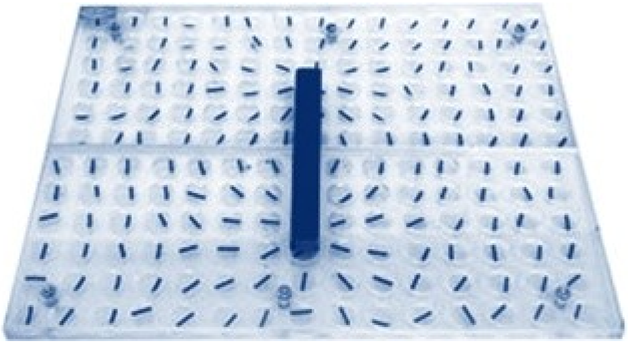
2.A bar magnet

Procedure

1.Take magnetic field demonstrator and a bar magnet from the carrying case.

2.Place the bar magnet at the center of the demonstrator.

3. Go on tapping the demonstrator across the bar magnet so that the magnetic pins (elementary magnets) align itself according to field lines of magnet as shown in Figure below.



Magnetic Field Demonstration

4.Now you can also take the image of the field lines on butter paper.

5.Place a butter paper on the demonstrator and draw the field lines of the magnet as shown by the demonstrator.

6.You can also view the field lines of magnet by driving it over the demonstrator.

This Magnetic Field Demonstrator allows one to demonstrate the magnetic field lines around a magnet.

Magnet Levitation

The fact that same magnetic poles repel each other is the base for design of many industrial types of equipment. Repelling magnets are often part of another electrical or mechanical system. When you attempt to move the north pole of one magnet toward the north pole of another magnet, initially the other magnet may be pushed away, but soon it flips over and the south pole of that flipping magnet face towards the north pole of first magnet and attract your magnet. So freely floating of magnets over one another with same poles facing each other i.e. magnetic levitation without any support is not possible. The problem is Earnshaw's theorem of 1850s.

The so-called Earnshaw's theorem explicitly states that, however hard you try, it is impossible to achieve stable levitation of a magnet in a system governed by stationary electric, magnetic and gravitational forces.

Earnshaw's Theorem proved that magnetic levitation only works along one axis – so for something to float on magnets there has to be an external force from another axis to stabilize it. You can see this by taking ring magnets and trying to float them over each other. They just squirt off to the side and stick to each other. But place them on a wooden or acrylic rod over one another with same poles facing each other, and they float. The rod provides that extra stabilizing force in another axis, so they don't just move off to the side and they are forced to float.

Two axial forces or supports are needed by magnets to float

1. Horizontal axial support due to dowel.
2. Vertical axial force on a magnet due to repulsive force of a magnet above and below it.

Many studies have been done on levitating objects with magnetic force, however it is now proven that 100% levitation for a non moving object is impossible. Partial levitation is now used in construction of high speed magnetic trains.

Generally speaking, a Maglev train uses huge electromagnets (usually superconducting electromagnets, because they are so powerful) to float the train over the electromagnets in the track. Like magnetic poles (such as North vs. North) repel, and opposite poles such as South Vs North attract. The train draws its power from overhead power lines to run the electromagnets. But to keep with Earnshaw's theorem, there are also electromagnets in the sides of the train, and in the side walls of the track–these keep it from slipping off the track, just like your ring magnets on a wooden or a acrylic dowel, but with no friction (other than air friction). Many MagLev trains use these bottom and side magnets to propel them and the computers that control the train and tracks sense where the train is, and rapidly reverse the polarity of the electromagnets as needed, so some are N-S, and attract each other. This pulls and pushes the train along, at incredible speeds because there's no friction of metal against metal like in a normal train. Many other instruments and equipment also use repelling properties of magnets.

Experiment 5

Objective

Study of Magnetic Levitation by Floating Ring Magnets.

Items required

1.Dowel (rod) with base

2.Set of 6 ceramic ring magnets

Procedure

1. Take the dowel with base and set of ring magnets.

2.Place the first ring magnet over the dowel and let it go down.

3.Get a second magnet and bring it close to the first magnet to feel the magnetic forces and find out which two poles repel each other. Then insert this magnet in such a way that when it gets to the first magnet, same poles are faced each other and two magnets will repel. So the second magnet will float.

4.Continue these steps with the other four magnets.

5.Finally you will have 6 ceramic ring magnets on a column that can freely float in air with horizontal support of dowel as shown in Figure below. These magnets float in air as gravity force is not able to pull them down because of the repulsive forces of other magnets. So floating magnets are getting support from two axes: horizontally from the dowel and vertically from the repulsive force of a magnet on another

Floating Ring Magnets

This helps us to understand Earnshaw's Theorem which states that "It is not possible to achieve static levitation using any combination of fixed magnets and electric charges". Static levitation means stable suspension of an object against gravity.

6. As we place more and more magnets one by one the distance between upper magnets increases. This is because magnet at the top is facing repulsive force only from one side only i.e. from the magnet below it and no repulsive force from above it. Similarly, second magnet from top is facing repulsive force from two sides, so distance between magnets decreases. In this way, other magnets are facing the repulsive forces of magnets above and below them and magnet at the lower side are facing more repulsive force than upper magnets and so the distance between the magnets at the bottom side starts decreasing.

This experiment helps student to understand the principle of Magnetic Levitation and Earnshaw's Theorem.

Oersted Experiment and Electromagnet

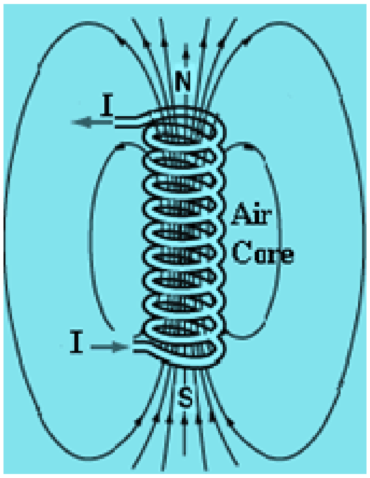
The connection between electricity and magnetism was rediscovered by a Danish physicist Hans Christian Oersted in 1820. During a lecture demonstration, Oersted observed that a magnetic compass needle aligned itself perpendicular to a current carrying wire. Oersted also noticed that when the direction of current in the wire was reversed, the direction in which the needle was pointed was also reversed. These observations led Oersted to conclude that a magnetic field is associated with an electric current.

The quantitative consequences of a steady current flow were established by four French physicists. Francois Arago demonstrates that a current carrying wire behaves like an ordinary magnet because of its ability to attract iron fillings. Andre Marie Ampere discovered that current carrying wires exert forces of attraction or repulsion on each other. He also determined the laws governing these interactions. Jean-Baptise Biot and Felix Savart determined experimentally the magnitude and direction of the magnetic field due to small current element.

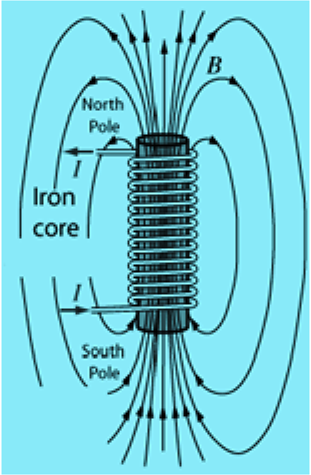
Electromagnet

An electromagnet is a type of magnet in which the magnetic field is produced by the flow of an electric current. The magnetic field disappears when the current ceases. The simplest type of electromagnet is a coiled piece of wire. It is usually wound around an iron core. However, it could be wound around an air core; in that case it is called a solenoid. A solenoid that is bent so that the ends meet is a toroid. Much stronger magnetic fields can be produced if a "core" (commonly soft iron) is placed inside the coil in place of air. The core concentrates the magnetic field that can be much stronger than that of the coil itself.

When connected to a DC voltage or current source, the electromagnet becomes energized, creating a magnetic field just like a permanent magnet. The magnetic flux density is proportional to the magnitude of the current flowing in the wire of the electromagnet. The polarity of the electromagnet is determined by the direction of the current. The north pole of the electromagnet is determined by using your right hand. Wrap your fingers around the coil in the same direction as the current is flowing (conventional current flows from + to -). The direction your thumb is pointing is the direction of the magnetic field, so north would come out of the electromagnet in the direction of your thumb. So South Pole is in the direction opposite to that of thumb. DC electromagnets are principally used to pick up or hold objects.



Inserting an iron core may give a magnetic field several hundred times that of the equivalent air core solenoid.



Current loop as a magnetic dipole

The face of the coil in which current appears to flow anti-clockwise acts as magnetic North Pole. The face of the coil in which current appears to flow clockwise acts as magnetic South Pole.

When connected to an AC voltage or current source, the electromagnet will be changing its flux density as the current fluctuates. The polarity of the magnet will also change as the current reverses direction every half cycle. AC electromagnets can be used to demagnetize objects (like TV screens, audio tapes, VCR tapes) or to hold objects. However, due to the inductance of the electromagnet, the AC current that will actually flow will be reduced when compared to a DC voltage equal to the RMS value of the AC voltage feeding the electromagnet.

The key importance of an electromagnet is the ability to control the strength of the magnetic flux density, the polarity of the field, and the shape of the field. The strength of the magnetic flux density is controlled by the magnitude of the current flowing in the coil, the polarity of the field is determined by the direction of the current flow, and the shape of the field is determined by the shape of the iron core around which the coil is wound.

Electromagnetic devices and inventions include a large magnet to lift up and drop automobiles, loudspeaker, electric motor, microphone, electric generator, and phonograph and maglev trains. Some devices use the opposite effects as others. The loudspeaker and microphone are examples of this.

Experiment 6

Objective

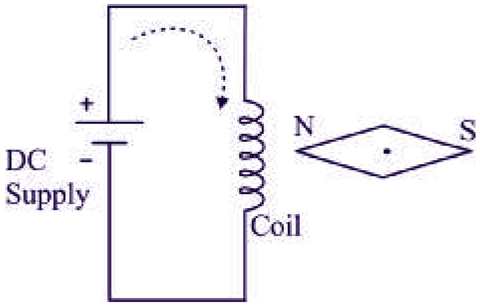
To study the Oersted's Experiment and study of Electromagnet.

Items required for Oersted's Experiment

1. Coil of 400 turns
2. Magnetic Compass
3. 5 V DC Power Supply (arrange from your laboratory)

Procedure

1. Take a 400 turns coil and compass.
2. Connect it to 5V DC power supply as shown in Figure below.



3. Now put magnetic compass near the coil, you can observe the deflection of the needle.
4. Now interchange the connection of coil. So the direction of current will be changed.
5. Now you can observe needle is also deflected reversely. This is the Oersted's experiment.

Items required for Electromagnet

1. Coil of 400 turns
2. Disc Magnet
3. Power supply of around 5V DC (arrange from your laboratory)

Procedure for demonstration of Electromagnet

1. Take the coil of 400 turns, power supply of 5 V and disk magnet (ceramic).
2. Connect the coil to 5V DC power supply.

3. Now bring the disk magnet near one end (face) of the coil. Magnet will either attract

or repel depending on the pole formed on that face of the coil. If same pole as of magnet's pole is formed on the coil then it will repel the magnet and if opposite pole to that of the magnet is formed on the coil then it will be attract the magnet.

4. Bring the magnet near the other end of the coil. Magnet will either repel or attract, opposite to that result in step 3.

5. Now interchange the connection of coil. So the direction of current will be changed.

6. Now again bring the magnet near the faces of the coil. You can observe that opposite poles to that of step 3 and 4 are formed. This is electromagnet.

Electromagnetic Induction

When Michael Faraday made his discovery of electromagnetic induction in 1831, he hypothesized that a changing magnetic field is necessary to induce a current in a nearby circuit. To test his hypothesis he made a coil by wrapping a paper cylinder with wire. He connected the coil to a galvanometer, and then moved a magnet back and forth inside the cylinder.

When the magnet is moved back and forth, the galvanometer needle moves, indicating that a current is induced in the coil. The needle immediately returns to zero when the magnet is not moving.

Faraday discovered that changes in a magnetic field could induce an electromotive force and current in a nearby circuit. The generation of an electromotive force and current by a changing magnetic field is called electromagnetic induction. Faraday confirmed that a changing magnetic field is necessary for electromagnetic induction to occur

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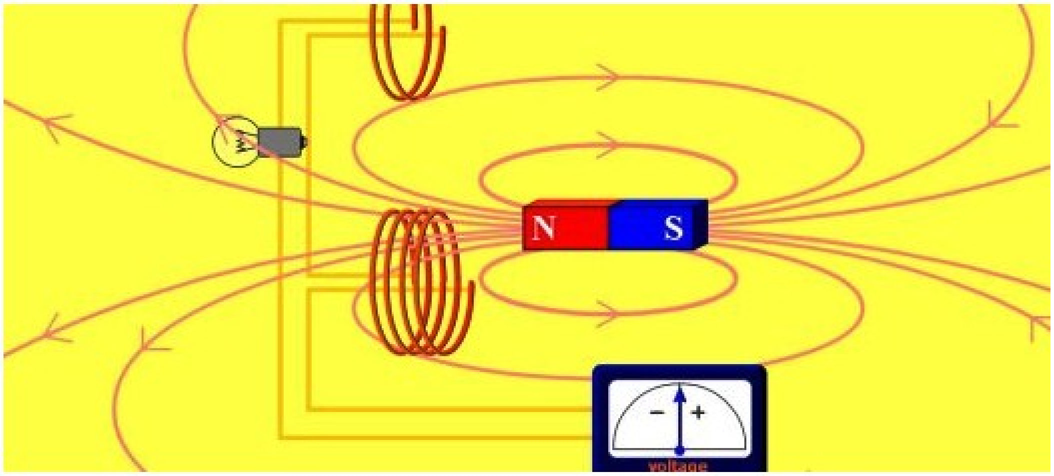


Courtesy by:
http://phet.colorado.edu/sims/faradays-law/faradays-law_en.html

Experiment 7

Objective:

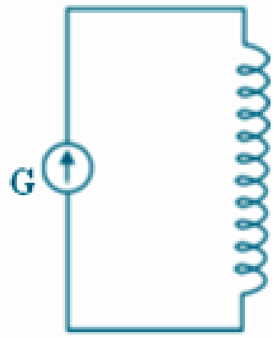
To understand Faraday's Law of Electromagnetic

Induction. Items required

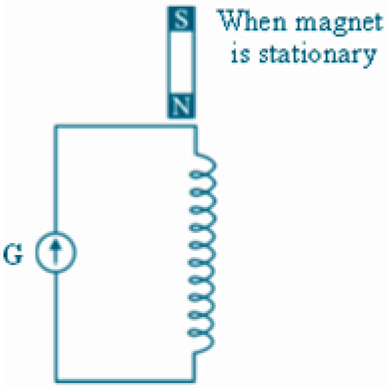
1. 400 turns coil
2. Bar magnet
3. Galvanometer (arrange from your laboratory).

Procedure

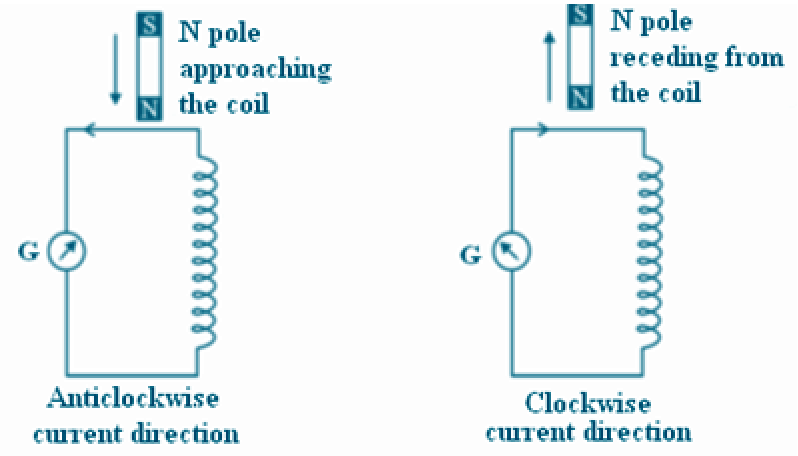
1. Take 400 turns coil and bar magnet from the magnetism kit.
2. Take a galvanometer and let the two ends of the coil be connected to the two terminals of galvanometer as shown in figure below.



3. Now take a bar magnet and keep its north pole stationary near one end of coil as shown in Figure below. The galvanometer shall not show any deflection when magnet is stationary.



4. When the magnet is moved towards the coil the galvanometer shows deflection as shown in Figure below.



5. When the magnet is moved away from the coil, the galvanometer again shows deflection but in opposite direction.
6. Similar results are obtained when the magnet is kept stationary and the coil is moved.
7. When the magnet is moved slowly the deflection in meter is small, but when the magnet is moved fast the deflection is large.
8. It is clear from above experiment that when magnetic flux changes through a coil, a current is induced in the coil.

Lenz’s Law

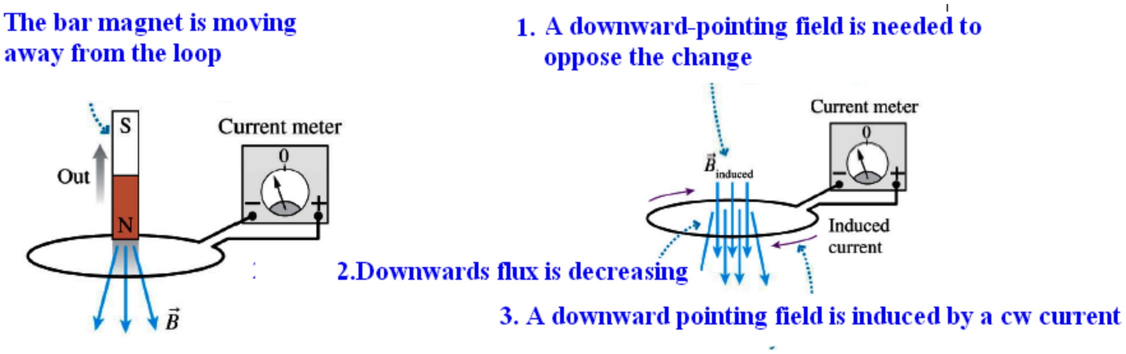
According to Faraday's Law of Induction, a changing magnetic field induces an electric field. According to Ampere's Law, a circulating current induces a magnetic field. If current is circulating anticlockwise then north polarity is induced and if current is flowing clockwise then south polarity is induced. So, if a magnetic field changes within a conductor, a current can be produced this in turn produces a secondary magnetic field. Lenz's Law states that this secondary magnetic field always opposes the change in the original field.

When the north pole of the magnet is moved down towards the Lenz’s law demonstrator surface, the direction of the induced current on the demonstrator surface will be such that the upper surface of the demonstrator acquires north polarity. So, the demonstrator surface repels the magnet. In other words, the demonstrator surface opposes the downwards motion of the magnet which is really the cause of the induced current on the demonstrator’s surface.

Similarly, if the south pole of a magnet is moved towards the demonstrator surface, the upper surface of the demonstrator will acquire south polarity thereby, opposing the motion of the magnet.

In other words

Lenz’s Law states that there is an induced current in a closed, conducting loop if and only if the magnetic flux through the loop is changing. The direction of the induced current is such that the induced magnetic field opposes the change in the flux.



Experiment 8

Objective

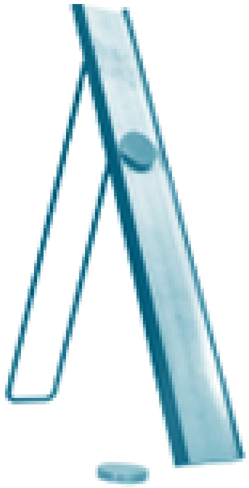
Study of Lenz's Law by Lenz's Law Demonstrator.

Items Required

1. Lenz's Law Demonstrator
2. Disk shape Neodymium Iron Boron (NIB) magnet
3. Disk shape Brass piece.

Procedure

1. Take the Lenz's Law Demonstrator, NIB magnet and brass piece.
1. Adjust the Lenz's Law Demonstrator at an angle of around 60º with the ground (horizontal). This adjustment will just give a slope to the demonstrator as shown in Figure below.



Lenz's Law Demonstrator

3.Now drop a brass piece from the top of the Lenz's Law Demonstrator through its surface and notice the speed with which brass is falling. You can also note the time required by brass piece to travel the slope with the stop watch.

4.Now, drop a NIB magnet of identical mass from the top of the Lenz's Law Demonstrator through its surface and notice the speed with which NIB magnet is falling. You can also measure the time with the stop watch.

5.You can easily observe that NIB magnet falls much slower than the brass piece. This is due to the Lenz's Law. Lenz's Law states that whenever there is change in magnetic flux, the direction of induced e.m.f is such that the polarity induced due to this e.m.f opposes the change that is producing it .In this demonstrator the falling NIB magnet produces a current on the demonstrator surface, which in turn produces a magnetic field that opposes the field of the falling magnet.

This opposing field slows the motion of the magnet, so it takes more time as long to fall through the surface. But when brass piece is dropped, there is no change in magnetic flux as brass is nonmagnetic. So there is no change in its falling speed.

The Lenz's Law Demonstrator provides a dramatic demonstration of Lenz's Law.

Homopolar Motor

A homopolar motor has a magnetic field along the axis of rotation of magnet and an electric current that is perpendicular to the magnetic field. Its action is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force. The name homopolar refers to the absence of polarity change.

Construction

Homopolar Motor consists of a battery, iron nail and a NIB magnet. A battery is at the top of the arrangement and a nail through its base is set at the center of the disk magnet. Now the other end of nail with disk magnet is touched to the lower end of battery. Now a top most end of battery and the side of magnet is connected through a patch cord.

Principle and Working

When you touch one end of the electrical supply wire to the side of the magnet and other end to the top most end of battery, electric circuit is completed. Current flows out of the battery, down the rod (which is between battery and NIB magnet), sideways through the magnet to the wire, and through the wire to the other end of the battery. The magnetic field from the magnet is oriented through its flat faces, so it is parallel to the magnet's axis of symmetry (magnet's axis of symmetry is vertical). Electric current flows through the magnet (on average) in the direction from the center of the magnet to the edge, so it flows in the radial direction, perpendicular to the magnet's axis of symmetry. The effect that a magnetic field has on moving electric charges is that it experience a force that is perpendicular to both their direction of movement and the magnetic field. Since the field is along the symmetry y axis of the magnet and the charges are moving radially outward from that axis, the force is in the tangential direction, and so the magnet begins to spin.

Its called a homopolar motor because you never need to reverse the polarity of any motor component during operation, unlike the other types of motors. In contrast to other electrical motors, both the orientation and magnitude of the magnetic field and the electric current do not change.

Motors of this design are currently being developed for quiet, high-power application.

Experiment 9

Objective

To study the principle of motor by a simple assembly of motor.

Items Required

1. Fixture of motor with battery -1.5 V
2. Iron nail
3. Disk shape NIB Magnet
4. Patch cord.

Procedure

1. Take fixture of motor with battery, iron nail and patch cord. Fix positive terminal or button end of battery to the lower side of terminal socket of fixture.
2. Set the iron nail base in the center of the disk magnet (NIB).
3. Bring the other end of iron nail with disk magnet to touch the negative terminal or lower end of battery.
4. Connect one end of patch cord to the terminal socket of the fixture and lightly touch other end of patch cord to the side of NIB magnet as shown in figure below.

Motor Assembly

5. Now you can see that NIB magnet and iron nail (connected between NIB magnet and battery) starts spinning either clockwise or anti-clockwise direction. Spin of motor can be reversed by either reversing the positive and negative terminals of battery or by flipping the magnet up side down.
6. This is the basic principle of a motor that in the presence of magnetic field, moving electric charges experiences a force that is perpendicular to both their direction of movement and the magnetic field.

Glossary

1. **Air Gap:** The distance between the north and south poles of a magnetic circuit. In conducting pull tests this is the distance between the working surface of the magnet and the testing apparatus.

2. **Anisotropic:** (oriented) A material that has a preferred direction of magnetic orientation which produces superior magnetic characteristics through a particular axis.

3. **Coercive Force, Hc :** The intensity of a magnetic field required to reduce to zero the residual magnetism of a substance.

4. **Curie Temperature:** The temperature that a magnetic substance loses its magnetic properties.

5. **Demagnetizing Force:** A magnetized force applied in a direction that reduces the field in a magnetized material.

6. **Electromagnets**: They rely upon electric current to generate a magnetic field. When the current increases, so does the field.

7. **Flux:** Another term for the magnetic field.

8. **Gauss:** The unit of magnetic induction or magnetic flux density used to measure magnetic field strength. (lines of magnetic flux per square centimeter).

9. **Gauss Meter:** An instrument used to measure the intensity of a magnetic field.

10. **Gradient:** Indicates the change in magnetic strength between points measured at different distances perpendicular to the magnetic field.

11. **Intrinsic Coercive Force, Hci :** Measurement of magnetic materials inherent ability to resist self demagnetization.

12. **Isotropic:** (non-oriented) A material with no preferred direction of orientation resulting in the same magnetic characteristics through any axis.

13. **Magnet:** A material that has the property, either natural or induced, of attracting iron or steel.

14. **Magnetic field**: A region of space near a magnetized body or electrical current where magnetic forces can be detected.

15. **Magnetic Flux:** The total magnetic induction across or through a specified area.

16. **Magnetic field lines:** These lines are a way to show the structure of a magnetic field. A compass needle will always point along a field line. The lines are close together where the magnetic force is strong, and spread out where it is weak.

17. **Magnetic Induction, B:** The production of magnetic properties in a magnetizable substance when placed in a magnetic field.

18. **Magnetic Lines Of Force:** A series of invisible lines passing from one pole to another of a magnet, which taken together form the magnetic field.

19. **Magnetic Orientation:** Determines the magnetic polarity and position of one magnet pole to the other.

20. **Magnetic Saturation:** The maximum amount of magnetic energy that can be absorbed by a magnetic substance.

21. **Maximum Energy Product, BH max :** The point on the BH curve where the product of B and H is a maximum and the required volume of magnet material required to project a given energy into its surroundings is a minimum. (MGOe)

22. **Maximum Operating Temperature:** The maximum temperature a magnet can withstand without significant long range instability or structural changes.

23. **Magnet solenoid:** A solenoid magnet is a coil of insulated wire, usually cylindrical in shape and with a length greater than its diameter. An electric current passing through the solenoid produces a magnetic field similar to that of a bar magnet.

24. **Magnetism (Electromagnetism):** A physical property of an object that shows attraction for iron, as in a magnet. Electromagnetism acts between particles with an electric charge, such as electrons, protons, and ions. It is associated with moving electricity, and it creates fields of force.

25. **Magnetometer:** An instrument that measures the magnitude (strength) and direction of a magnetic field.

26. **Magnetosphere:** The region surrounding a planet where the planet's magnetic field dominates.
27. **MGO :** Mega Gauss Oersted

28. **North Pole:** The pole of a magnet that when freely suspended would point to the north magnetic pole of the earth.

29. **Oersted:** The unit of magnetic intensity in the cgs (centimeter-gram-second) system that describes magnetic force.

30. **Pole Pieces:** Steel plates attached to the north and south poles of a magnet which direct the lines of flux and can control the gradient of the magnetic field.

31. **Pull Test:** A test of holding value or breakaway force and reach out, usually conducted with a flat ferrous plate or ferrous sphere and a spring scale.

32. **Permanent magnets:** They do not rely upon outside influences to generate their field. They retain their magnetism for a long time.

33. **Reach Out:** The distance in which a magnetic field will extend from the magnet source.

34. **Residual Magnetism:** Small amounts of magnetism that remains in a material after being exposed to magnetic force.

Frequently Asked Questions

Q1. What is a magnet?

Ans. Magnets can be made by placing a magnetic material such as iron or steel, in a strong magnetic field. Permanent, temporary and electromagnets can be made in this manner.

Q2. What does a magnet do?

Ans. Magnets do the following things:

- Attract certain materials - such as iron, nickel, cobalt, certain steels and other alloys;
- Exert an attractive or repulsive force on other magnets (opposite poles attract, like poles repel);
- Have an effect on electrical conductors when the magnet and conductor are moving in relation to each other;
- Have an effect on the path taken by electrically charged particles traveling in free space.

Q3. What are permanent magnets made of?

Ans. Modern permanent magnets are made of special alloys that have been found through research to create increasingly better magnets. The most common families of magnet materials today are ones made out of Aluminum-Nickel-Cobalt (Alnicos), Strontium-Iron (Ferrites, also known as Ceramics), Neodymium-Iron-Boron (Neo magnets, sometimes referred to as "super magnets"), and Samarium-Cobalt. (The Samarium-Cobalt and Neodymium-Iron-Boron families are collectively known as the Rare Earths.)

Q4. How are magnets made?

Ans.Modern magnet materials are made through casting, pressing and sintering, compression bonding, injection molding, extruding, or calendaring processes.

Q5. What is a temporary magnet?

Ans. Soft iron and certain iron alloys, such as Permalloy (a mixture of iron and nickel) can be very easily magnetized, even in a weak field. As soon as the field is removed, however, the magnetism is lost. These materials make excellent temporary magnets that are used in telephones and electric motors for example.

Q6. What are electromagnets?

Ans. An electromagnet is a type of magnet in which the magnetic field is produced by the flow of electric current. The magnetic field disappears when the current is turned off.

Q7. What are superconductors?

Ans. These are the strongest magnets. They don't need a metal core at all, but are made of coils of wire made from special metal alloys which become superconductors when cooled to very low temperatures.

Q8. How permanent is a magnet's strength?

Ans. If a magnet is stored away from power lines, other magnets, high temperatures, and other factors that adversely affect the magnet, it will retain its magnetism essentially forever.

Q9. Will magnets lose their power over time?
Ans. Modern magnet materials do lose a very small fraction of their magnetism over time. For Samarium Cobalt materials, for example, this has been shown to be less that 1% over a period of ten years.

Q10. What might affect a magnet's strength?
Ans. The factors can affect a magnet's strength:

- Heat
- Radiation
- Strong electrical currents in close proximity to the magnet
- Other magnets in close proximity to the magnet
- (Neo magnets will corrode in high humidity environments unless they have a protective coating.)

Shock and vibration do not affect modern magnet materials, unless sufficient to physically damage the material.

Q11.Can a magnet that has lost its magnetism be re-magnetized?
Ans. Provided that the material has not been damaged by extreme heat, the magnet can be re-magnetized back to its original strength.

Q12. What is the strength of the Earth's magnetic field?
Ans. The surface field strength of the Earth is about 0.5 gauss, but it varies by as much as 10% depending on the strength of the crustal field. A range from 0.85 to 0.45 can be found across the globe. Geomagnetic storms can cause changes of between 1% to 5% that last from hours to a day or so.

Q13. What are Magnetic Poles?
Ans. Magnetic Poles are the surfaces from which the invisible lines of magnetic flux emanate and connect on return to the magnet.

Q14. What are the standard industry definitions of "North" and "South" Pole?
Ans. The North Pole is defined as the pole of a magnet that, when free to rotate, seeks the North Pole of the Earth. In other words, the North Pole of a magnet seeks the North Pole of the Earth. Similarly, the South Pole of a magnet seeks the South Pole of the Earth.

Q15. Can a particular pole be identified?
Ans. Yes, the North or South Pole of a magnet can be marked if specified.

Q16.How can you tell which is the North Pole if it is not marked?
Ans. You can't tell by looking. You can tell by placing a compass close to the magnet. The end of the needle that normally points toward the North Pole of the Earth would point to the South Pole of the magnet.

Q17.What are Rare Earth Magnets?
Ans. Rare Earth magnets are magnets that are made out of the Rare Earth group of elements. The most common Rare Earth magnets are the Neodymium-Iron-Boron and Samarium Cobalt types.

Q18. Which are the strongest magnets?

Ans. The most powerful magnets available today are the Rare Earths types. Of the Rare Earths, Neodymium-Iron-Boron types are the strongest. However, at elevated temperatures (of approximately 150°C and above), the Samarium Cobalt types can be stronger than the Neodymium-Iron-Boron types (depending on the magnetic circuit).

Q19. What are eddy currents?
Ans. These are electrical currents that are induced when a magnetic field moves in relation to an electrical conductor, which is placed within reach of the magnetic field. In turn, these eddy currents create a magnetic field that acts to stop the relative motion of the original magnetic field and electrical conductor.

Q20. What is meant by residual magnetism?
Ans. The ability to retain some magnetism in the core after magnetisation has stopped is called Retentivity or Remanence while the amount of flux density still present in the core is called Residual Magnetism, BR .

Q21.What is critical field resistance?
Ans. The field resistance above which a generator cannot build up voltage is called critical resistance.

Q22. What is meant by saturation?
Ans. It is point after the magnetic flux density becomes constant even though there is an increase in magnetic field strength.

Q23. What are the reasons for the drooping load characteristics?
Ans. The reasons for drooping characteristics load characteristics are armature reaction and armature voltage drop.

Q24. What is Lenz's Law?

Ans. The law that whenever there is an induced electromotive force (e.m.f) in a conductor, it is always in such a direction that the current it would produce would oppose the change which causes the induced e.m.f.

Q25. What is Faraday's Law?
Ans. The induced electromotive force in any closed circuit is equal to the negative of the time rate of change of the magnetic flux through the circuit.

Warranty

1) We guarantee the instrument against all manufacturing defects during 12 months from the date of sale by us or through our dealers.

2) The guarantee covers manufacturing defects in respect of indigenous components and material limited to the warranty extended to us by the original manufacturer and defect will be rectified as far as lies within our control.

3) The guarantee does not cover perishable item like cathode ray tubes, crystals, batteries, photocells etc. other imported components.

4) The guarantee will become **INVALID.**

- **a)** If the instrument is not operated as per instruction given in the instruction manual.
- **b)** If the agreed payment terms and other conditions of sale are not followed.
- **c)** If the customer resells the instrument to another party.
- **d)** If any attempt is made to service and modify the instrument.

5) The non-working of the instrument is to be communicated to us immediatel y giving full details of the complaints and defects noticed specifically mentioning the type and sr. no. of the instrument, date of purchase etc.

6) The repair work will be carried out, provided the instrument is dispatched securely packed and insured with the railways. To and fro charges will be to the account of the customer.

Note: Compass & Battery are not covered in the warranty.

List of Accessories

1.	Bar Magnet (Alnico)	1 No.
2.	Cylindrical Magnet (Alnico)	1 No.
3.	U- Shape Magnet (Alnico)	1 No.
4.	Horse-shoe Magnet (Alnico)	1 No.
5.	Ring Magnet (Ceramic or ferrite)	5 Nos.
6.	Disc Magnet	
·	Ceramic or ferrite	1 No.
·	Neodymium-Iron-Boron	1 No.
7.	Magnetic Compass	1 No.
8.	Silver (Small) Magnetic Compass	1 No.
9.	Magnetic Field Demonstrator Plate	1 No.
10.	Lenz’s Law Demonstrator	1 No.
11.	Motor Assembly with a battery	1 No.
12.	Dowel	1 No.
13.	Coil	1 No.
14.	Iron Nail	1 No.
15.	8” Patch cord	1 No.
16.	Learning Material CD	1 No.

References

1. http://www.intemag.com/faqs.html#basics
2. http://greatworld-e-world.blogspot.in/2012/03/qwhat-is-meant-by-residual-magnetism.html
3. http://en.wikipedia.org/wiki/Faraday%27s_law_of_induction