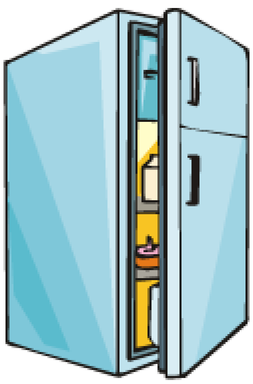
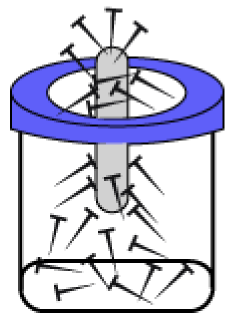
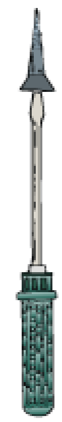
Magnetism

Magnet - An Introduction

You are familiar with the fact that magnets have a variety of applications in our daily lives. Magnets are used in refrigerator doors, in junkyards, as pin holders, in screwdrivers, etc.

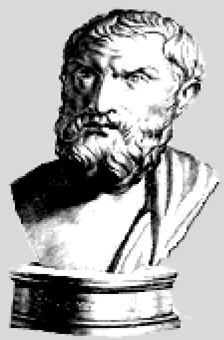
A question that can arise in our minds is how magnet was discovered. In this section, we will tell you an interesting story about the accidental discovery of magnet.

Around 2,000 B.C., a shepherd named **Magnes** lived in an area named **Magnesia** (situated in Northern Greece). He used to take his herd of sheep to graze in the nearby mountains. He used to control his herd with a long stick that had an iron tip. Also, a few iron nails were fixed to his shoes.

It is said that one day while he was herding his sheep, he observed that his shoes and the tip of the stick were stuck to a large black-coloured rock. It was very difficult for him to move on that black rock. Later, this rock and similar rocks were named **magnetite** (after either his name or that of the place). Magnetite has the property to attract objects made up of iron. The substances that can attract iron are now known as **magnets**.

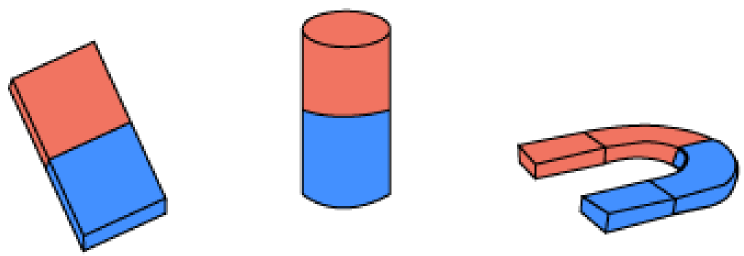
Do You Know:

Lucretius was the first person who wrote magical stories about magnets around the first century BC.



Magnetite is the natural magnet. It is found in the form of rocks. Sometimes, magnetite is found in large quantities in beach sand. It is also found in the brain of bees, some birds, and in humans

With the passage of time, people learned to make magnets from iron pieces. These magnets are known as **artificial magnets**. Like natural magnets, these artificial magnets can also attract iron objects. With the help of modern technology, artificial magnets having different shapes (for example, bar magnets, cylindrical magnets, and horseshoe magnets, spherical magnets) are also made.



a) Bar magnet b) Cylindrical magnet c) Horseshoe magnet

Remember, all the magnets, natural or artificial, always have two poles know as North-Pole (N) and South-Pole (S).

Let us have some fun with a magnet.

Find more on the discovery of magnets from this video

Attractive Property

Attach a magnet to one end of a long stick. Now, hold the stick and drag the other end (the one having the magnet attached to it) on the soil present in areas such as your garden, backyard, playground, and school. You will find that some soil particles stick to the magnet.

When you observe these small particles carefully, you will see that they are iron filings. Make a table listing the amount of iron filings present in the soil at different locations. **Where do you find the greatest amount of iron filings?**

Naina has a box in which she keeps all the materials that are required during stitching such as spools of thread, wool, buttons, needles, and small bits of cloth. She is not able to find the needle in her box. **What is the easiest way to find the lost needle?**

Refrigerator stickers: Have you seen stickers that remain attached to the surface of refrigerators? These stickers have magnets attached to them. **Why do the stickers stick to the door of a refrigerator?**

Refrigerators are made up of magnetic material (iron). Hence, stickers having magnets stick to refrigerators.

From the given examples, you can easily make out the most important property of a magnet—**a magnet attracts objects made up of iron**. **This is called attractive property of magnet.** Apart from iron, the other materials that a magnet attracts are nickel, cobalt.

Magnetic and Non-Magnetic Materials

A visit to the junkyard

In a junkyard, there are many materials that can be recycled. First, the materials that are to be recycled have to be separated from the materials that cannot be recycled. This is usually done by using cranes. A crane has a large magnet at the end of its long mechanical arm. This is used to separate materials made up of iron from the rest of the junk. **How can the crane separate materials made up of iron so easily?**

All materials can be classified into two categories based on their behaviour towards a magnet.

Materials that get attracted toward magnets are known as ***magnetic materials***.

Materials that do not get attracted toward magnet are known as ***non-magnetic materials***.

Iron balls, nails, and coins are made up of magnetic materials as they are attracted toward magnets. Plastic scales, leather shoes, and candles are made up of non-magnetic materials as they are not attracted toward magnets.

Shamsher is a carpenter. One day, he accidentally drops some iron nails in a heap of wooden shavings. **How can he easily separate the nails from the wooden shavings?**

The magnet attached at the end of the mechanical arm of a crane is used to separate magnetic materials, i.e., those made up of iron, from the rest of the junk.

The given table lists some common materials/objects as magnetic and non-magnetic.

Material/Object	**Is it attracted by a magnet?**	**Magnetic or non-magnetic**
Iron nail	Yes	Magnetic
Plastic scale	No	Non-magnetic
Wooden block	No	Non-magnetic
Paper	No	Non-magnetic
Glass	No	Non-magnetic
Coin	Yes	Magnetic
Metallic clip	Yes	Magnetic

Drawing pin	Yes	Magnetic

Identifying magnetic materials

Get a magnet, try sticking it on various materials around you, and classify them as magnetic and non-magnetic. The magnet will be attracted only toward magnetic materials.

Iron in sand!

Attach a magnet to one end of a long stick. Now, hold the stick and drag the other end (the one having the magnet attached to it) on the soil present in areas such as your garden, backyard, playground, and school.

You will find that some soil particles stick to the magnet. When you observe these small particles carefully, you will see that they are iron filings. Make a table listing the amount of iron filings present in the soil at different locations. **Where do you find the greatest amount of iron filings?**

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Refrigerator stickers:

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Pin Holders:

You must have seen that in some pin holders, the pins stick to the cap of the holder. **Why do the pins stick to the cap?**

The pins are made up of magnetic material and the cap of the holder houses a magnet. Hence, the pins stick to the cap of the pin holder.

Tightening a screw:

When you use a screwdriver to tighten or loosen a screw, you might have seen that the screw sticks to the screwdriver easily. **Why does the screw stick to the screwdriver?**

A screwdriver has a small piece of magnet attached to its end and screws are made up of magnetic material. Therefore, a screw can be tightened or loosened easily using a screwdriver.

Identifying Directions Using a Magnet

Ramdin is a fisherman who often sails in the sea to catch fish. He always carries a marked magnet to help him in identifying the directions. **How does this magnet help him in locating the correct direction?**

Do you know that **a bar magnet, when suspended freely, always comes to rest in the North-South direction.** You can confirm this fact by suspending a marked magnet by a thread. Notice the direction pointed by its marked end when it comes to rest.

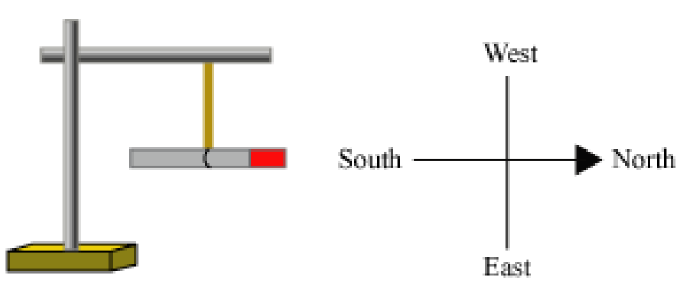
Marking a bar magnet using the position of the sun

Stand on your roof with your face toward the sun in the morning. Since you are facing the East, your left hand will be toward the North and your right hand will be toward the South. Suspend a bar magnet and allow it to rotate freely.

When it comes to rest, mark the end that points toward your left with red ink. Hence, your magnet becomes a **marked magnet**. The marked end of the magnet will indicate the North direction when suspended freely with a thread.

Identifying the four directions

To identify the four directions using your marked magnet (the marked end points toward the North), suspend the marked magnet with a thread, and wait until it comes to rest. The marked end will point toward the North, while the unmarked end will point toward the South, as shown in the given figure.



The magnet helps Ramdin in identifying the directions because when suspended freely, a magnet always aligns itself in the North-South direction.

In the making and working of a magnetic compass, the property of the North-South alignment of a magnetic needle is used.

In ancient times, sea travellers used to identify the directions with the help of marked bar magnets suspended by threads.

Rajeev’s teacher gives him two identical, red-coloured needles. His teacher tells him that one is a magnetised needle, while the other is an ordinary iron needle and asks him to identify the magnetised one. How can Rajeev do so?

Magnetic compass

A simple magnetic compass

With the help of a magnetic compass, you can know the directions at a particular place. The red end of the needle indicates the North direction. Rotate the compass in such a way that its red end directly points to the letter ‘N’ of the compass. Now, observe all the four alphabets marked on the compass. These letters indicate the four directions at that particular place, in the same order.

Take a bar magnet and label its ends as **A** and **B**. **How would you determine which letter is on the north pole of this magnet?**

A bar magnet

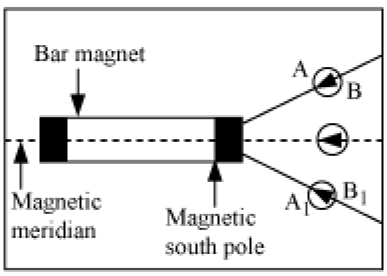
Do You Know:

A Chinese emperor named Hoang Ti had a specially designed chariot having a statue of a lady fixed on it. The statue, which could freely rotate about an axis, had an extended arm to show the direction.

It was said that the extended arm of the lady always pointed toward the South when it came to rest. In this way, the emperor could locate his way when he was at a new place.

Why did the extended arm of the lady always point toward the South?

Magnetic Poles



- Take a white sheet of paper and fix it on a wooden drawing board.
- In the middle of the white sheet, draw a straight line.
- Place a magnetic compass needle on the drawing board and turn the board in clockwise or anticlockwise direction to align the needle with the line drawn on drawing board.

At this point, the drawing board is said to be in magnetic meridian.

- Place a bar magnet instead of the magnetic needle such that its axis coincides with the line on the paper.
- Mark the outline of the magnet.
- Place the compass needle near one end of the bar magnet.

As the action of the earth's field is ineffective along the magnetic meridian, the compass needle will not show any deflection because of the earth's magnetic field. The compass needle is only attracted by the nearest pole of the magnet at this position.

- Mark the two ends of the needle by two dots as shown in the figure.
- Now, change the position of the compass needle and repeat the whole process for the new position of the needle. Take two such marks by placing the compass at two different places.
- Join the two marks by straight lines.

- You will see that the straight lines meet near the end of the magnet.
- It is this point of intersection that indicates the exact position of the magnetic pole of the bar magnet.

Try to find out the exact position of the other pole of the magnet.

The length between the two poles is called the effective length of the magnet. It is observed that the effective length of a magnet is 0.84 times the length of the real magnet.

So, have you found the answer to the question – **why a magnetic compass always aligns itself along the North-South direction**?

So far you have learned that *opposite poles of magnets attract each other whereas like poles of magnets repel each other.*

The answer to the question lies in this property of a magnet.

A magnetic compass works on this principle because the earth is considered as a huge bar magnet with its North and South poles aligned along the geographical South and North Poles respectively.

Hence, the North pole of the magnetized needle in a magnetic compass is attracted towards earth's geographic North Pole and the South pole of the magnetized needle is attracted towards earth's geographic South Pole. Hence, the magnetized needle of a magnetic compass always aligns itself along the North-South direction.

Some interesting facts:

- Did you know that the only repulsive force that you have studied about is the magnetic force?
- Repulsion is considered the sure way for testing magnets. Do you know why?

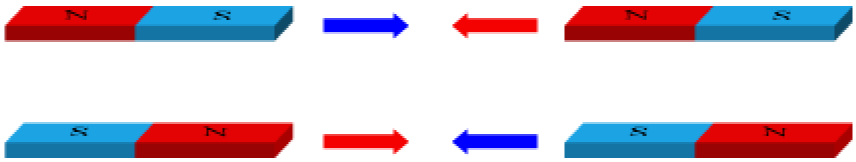
Magic trick

Pooja goes to a village fair. There, she sees a magic trick in which a frog is made to hover magically over a table defying earth's gravity. Pooja observes that the magician had slipped a magnet below the table and this made the frog rise in the air. **What made the frog rise in the air in the presence of the magnet?**

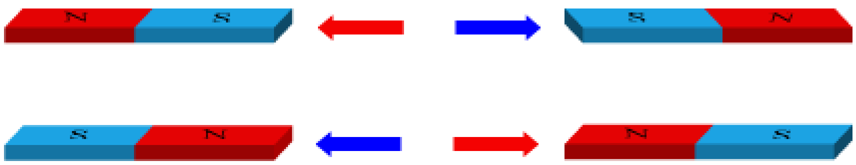
The frog behaves like a magnet. Hence, it is repelled by the permanent magnet placed below the table.

Like poles repel each other and unlike poles attract each other

- When north pole of one magnet is brought near to south pole of another magnet, we will observe that the poles will attract each other. Thus, we can say unlike poles of magnets attract each other.



- When two north poles or two south poles of magnets are brought close to each other, we will observe that the poles will repel each other. Hence, we can say like poles of magnets repel each other.



Repulsion is the sure test for a magnet

A magnet can either attract or repel another magnet, depending upon the type of poles. However, a magnet will always attract an un-magnetised magnetic material. Hence, attraction can take place for both but repulsion will take place only with a magnet. Hence, repulsion is a surer way of differentiating between an un-magnetised magnetic material and a magnet.

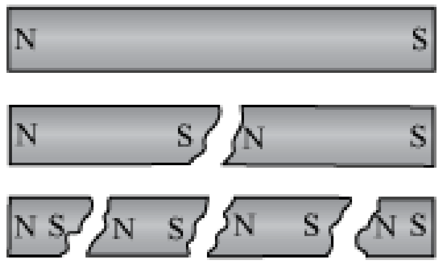
Magnetic poles always occur in pairs

Niraj has a bar magnet. He breaks it into two pieces. He then brings the broken ends of the pieces close to each other. To his surprise, the broken ends attract each other.

Again he brings the broken end of one piece to the smooth end of the other piece. This time he observes that the pieces repel each other. **Can you explain why this happens?**

This is because **magnetic poles always occur in pair** i.e., you cannot separate a single pole of a magnet by breaking it into pieces.

When you break a bar magnet, each piece of the broken magnet behaves similar to a separate bar magnet. Therefore, every piece will have one North Pole and one South Pole in it.

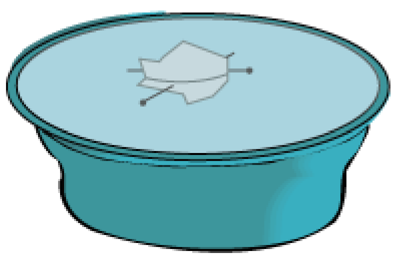


Artificial Magnets

Try to convert a nail into an artificial magnet by the touch-stroke method.

Take two identical iron pins and magnetize them by the touch and stroke method. Make sure that you are stroking both the pins with equal number of strokes so that they have the same strength as magnets. Now, take a small piece of thermocol and insert both the pins, as shown in the given figure.

Place this piece in a small tub filled with water so that it can float. Gently rotate the piece in a particular direction and then observe its motion. **Can you guess when this piece of thermocol will stop rotating?**

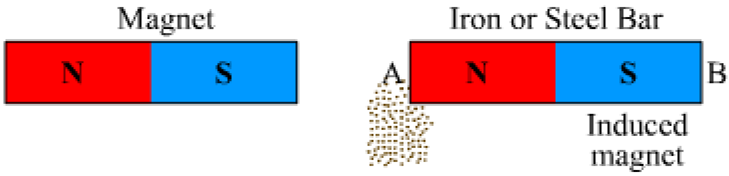


Collect some objects. For example, a comb, a blade, a toothbrush, a nail, a needle, a stainless steel spoon, etc. Now, try to magnetize them one by one by stroking them about 100 times with a magnet. After stroking them, bring a pin near each of these objects. **Do all the objects attract the pin?**

Induced Magnetism

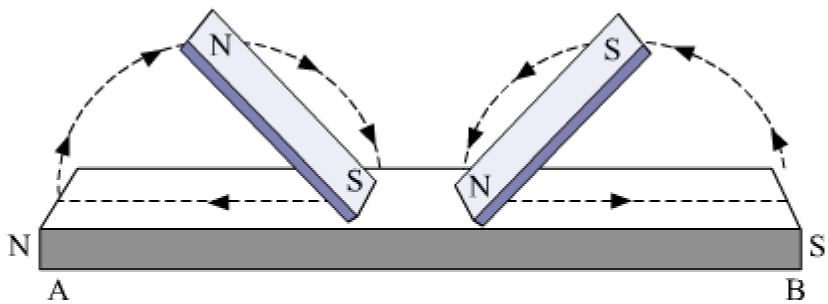
When an unmagnetised magnetic material such as soft iron or steel is placed near or in contact with a permanent magnet, it acquires the property of magnet and gets magnetised.

Now if the permanent magnet in contact with the material is removed, then the material loses its magnetism. This temporarily acquired magnetism is known as induced magnetism.



Try to convert an iron bar into an artificial magnet by double touch method.

Place an iron bar on a table. Take two bar magnets and place them vertically at the centre of the iron bar with their unlike poles facing each other. Move the magnets on the iron bar several times without changing the poles and direction. Now, when this iron bar is brought near some iron fillings, it is going to attract them showing that the iron bar is magnetised.



Characteristics of Magnetic Field Lines

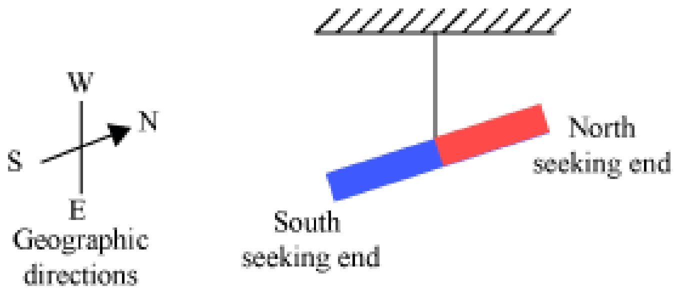
Construct a simple circuit with open ends M and N. Take a thick conducting wire of aluminium and connect it between the open ends. Now, place a magnetic compass near the aluminium wire and note the position of the compass needle. Now, close the switch to allow the current to flow through the wire and notice the deflection in the needle.

It can be concluded from this activity that electric current flowing through aluminium wire has produced a magnetic force that is exerted on the compass needle resulting in its deflection. **Can we say that a magnetic field is related to an electric current?**

Hans Christian Oersted (1777-1851) was the first scientist to observe that a compass needle gets deflected when placed near a current carrying conductor. By this, he concluded that electricity and magnetism are related to each other and called it electromagnetism.	

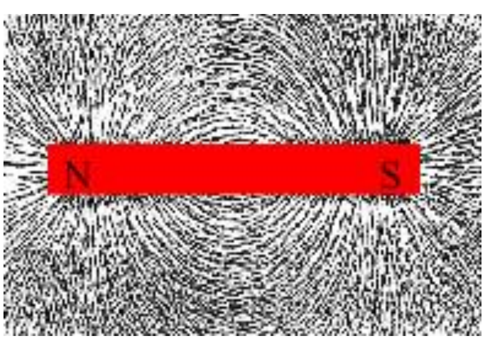
Magnetic lines of force (magnetic force)

You know that a bar magnet can repel or attract another magnet depending on the nature of poles of the other two magnets that are facing each other. When a bar magnet is suspended by thread, its one end always points towards the geographic North Pole, called **magnetic North Pole** and the other end always points towards the geographic South Pole, called **magnetic South Pole** of the magnet.



Like poles repel and unlike poles attract each other.

Take a drawing cardboard and sprinkle some iron filings on it. Notice the position of the iron filings as a whole. Now, take a bar magnet and slowly bring it below the cardboard. You will observe that the iron filings tend to attract towards the magnet.



It is observed that most of the iron filings align themselves at poles. **What does the pattern represent?** It represents that the magnet exerts a force around its body with a stronger force near the two poles. A magnet produces a magnetic field, which can be detected by the force exerted on the iron filings. The regular pattern of the iron filings on the board represents the lines of magnetic field or lines of magnetic force called **magnetic lines**.

How to determine the shapes of magnetic field lines of a bar magnet?

To understand the process, let us see this animation

Do you know the direction of a magnetic field inside the magnet?

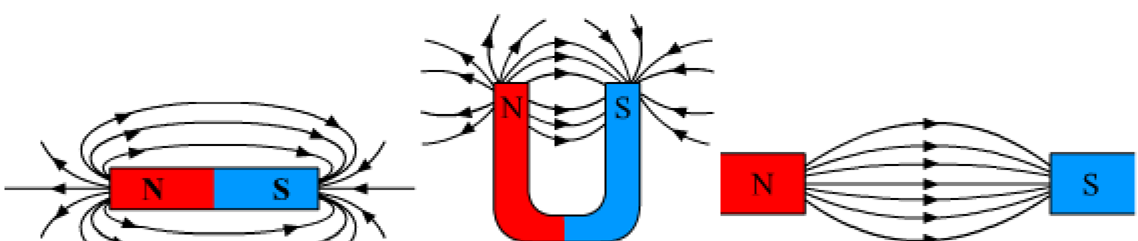
Inside the magnet, magnetic field lines run from the South Pole to the North Pole where they emerge out. Therefore, we can say that magnetic field lines make closed curves.

- The region where magnetic field lines are crowded has relatively greater strength. Hence, in a magnet, strength of the regions near the poles is greater than other regions.
- It should be noted that a compass needle cannot point in two directions when placed at a point near the magnet. This means that no two magnetic field lines cross each other at a point.

Characteristics of magnetic field lines

1. Magnetic field lines emanate from the North Pole and terminate at the South Pole of a magnet. (Outside the magnet)
2. The degree of closeness of magnetic field lines represents the relative strength of the magnet.
3. No two field lines can intersect each other.

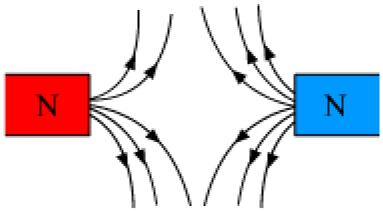
Non-uniform magnetic field due to stronger magnets



Magnetic field lines due to a bar magent

Magnetic field lines due to a horse shoe magnet

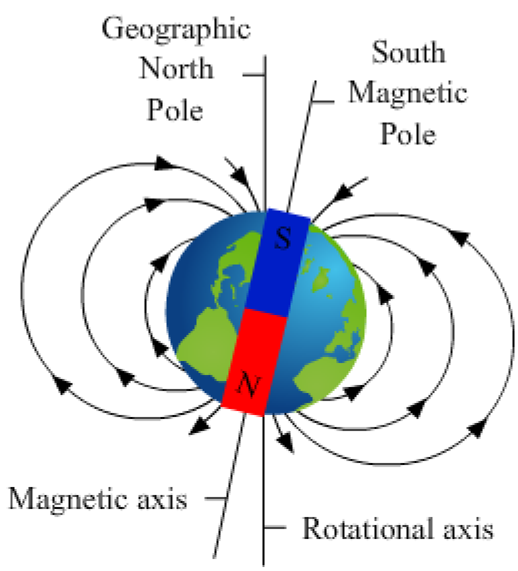
Magnetic field lines due to two unlike poles facing each other



Magnetic field lines due to two like poles facing each other

Magnetic field lines of the Earth

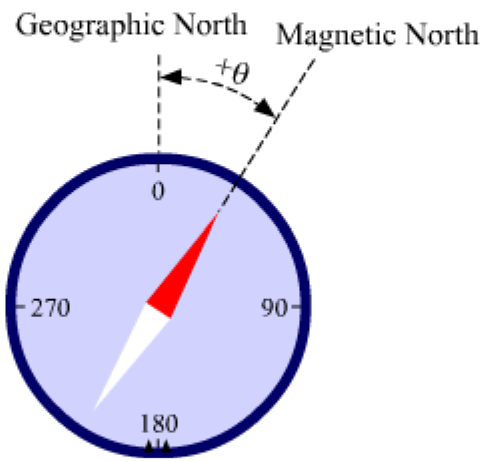
The Earth is treated as magnetic because it is assumed that a huge bar magnet is buried within its interior with the magnetic North Pole near the geographic South Pole, and the magnetic South Pole near the geographic North Pole respectively.



Since magnetic field lines originate from the magnetic North Pole and end at the magnetic South Pole, the Earth's magnetic field lines originate from its geographic South Pole and end at its geographic North Pole respectively.

The magnetic poles of the Earth continuously change their position with time i.e., the magnetic North Pole becomes the magnetic South Pole and vice-versa. This phenomenon of flipping of poles is known as **magnetic reversal**. It is assumed by scientists that the Earth's magnetic field has undergone 170 such reversals in the past 100 millions years.

We have learnt that when a magnetic compass is suspended freely, it aligns itself in geographic North-South direction. But in actual, the North pole of the magnetic needle is not exactly along the geographic North. This is depicted in the figure below.



Thus, the angle of the horizontal plane between the geographic North (true North) and the magnetic North as shown in the above figure is known as **magnetic declination**. The magnetic declination varies with time and place.

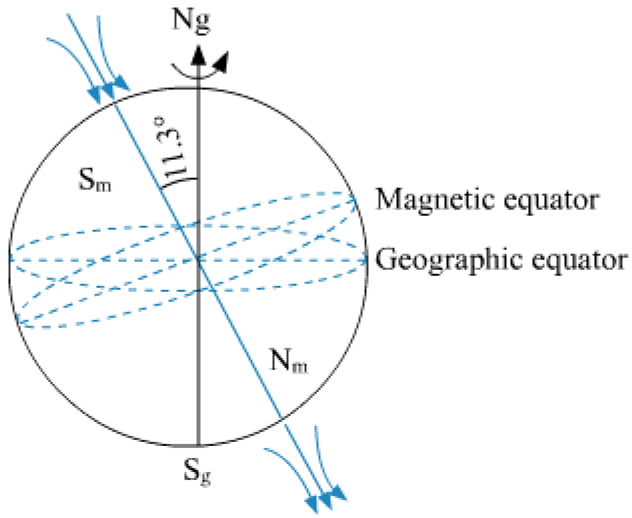
- If magnetic North is towards East of true North, declination is taken positive.
- If magnetic North is towards West of true North, declination is taken negative.

Bar Magnet and Earth's Magnetism

Dynamo effect − The magnetic field of earth has arisen due to electrical currents produced by convective motion of metallic fluids in the outer core of the earth. This is known as the dynamo effect.

The magnetic field lines of the earth resemble that of a magnetic dipole located at the centre of the earth. The axis of the dipole is presently tilted by approximately 11.3° with respect to the axis of rotation of earth.

The North magnetic pole is located at latitude of 79.74° N and a longitude of 71.8° W, a place somewhere in North Canada. The magnetic South Pole is at 79.74° S and 108.22° E in Antarctica.



The pole near the geographic North Pole of the earth is called the south magnetic pole and the pole near the geographic South Pole is called the north magnetic pole.

- **Geographic meridian −** The vertical plane passing through the geographic North −South direction is called geographic meridian.

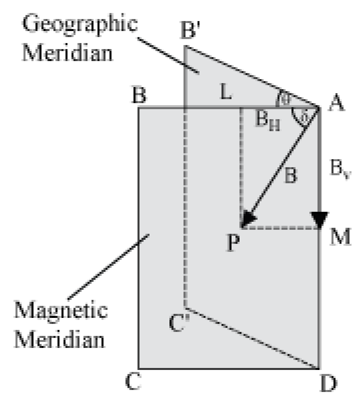
- **Magnetic Meridian −** The vertical plane passing through N − S line of a freely suspended magnet is called magnetic meridian.

Magnetic Declination and Dip (or Magnetic Elements)

- **Magnetic elements −** The physical quantities, which determine the intensity of earth's total magnetic field completely (both in magnitude and direction), are called magnetic elements.

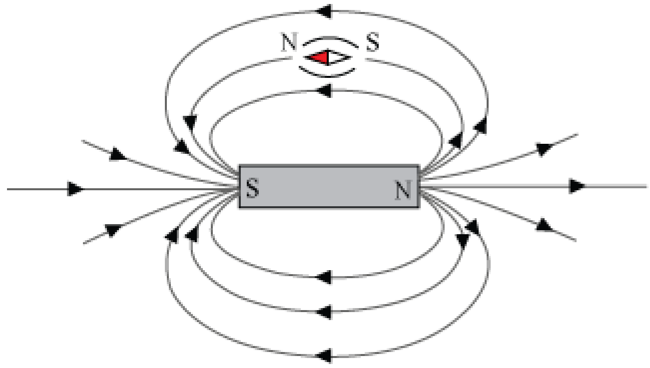
- There are three magnetic elements of earth:

- **Magnetic declination −** Declination at a place is the angle between the geographic meridian and magnetic meridian. It is denoted by *θ*.

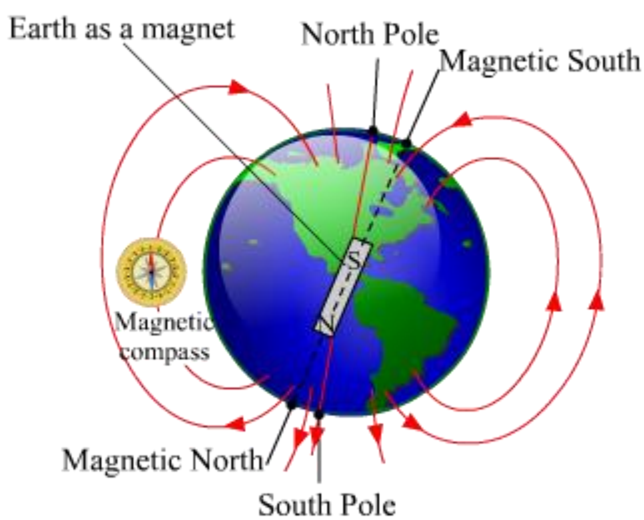


- **Magnetic inclination or dip −** Dip at a place is defined as the angle made by the direction of the earth's total magnetic field with the horizontal direction. It is denoted by *δ*.

  When freely suspended, a bar magnet comes to rest in the North-South direction. This is because the Earth also behaves like a magnet, larger than any magnet in general use.

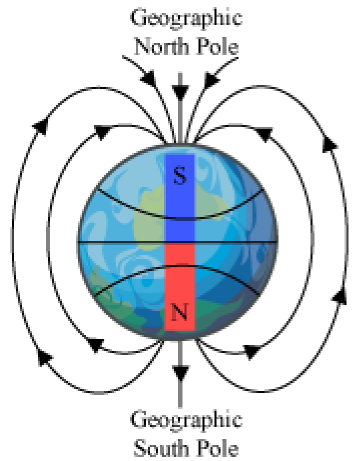


  The north pole of the Earth's magnet is near the geographical South Pole and the south pole of the Earth's magnet is near the geographical North Pole.



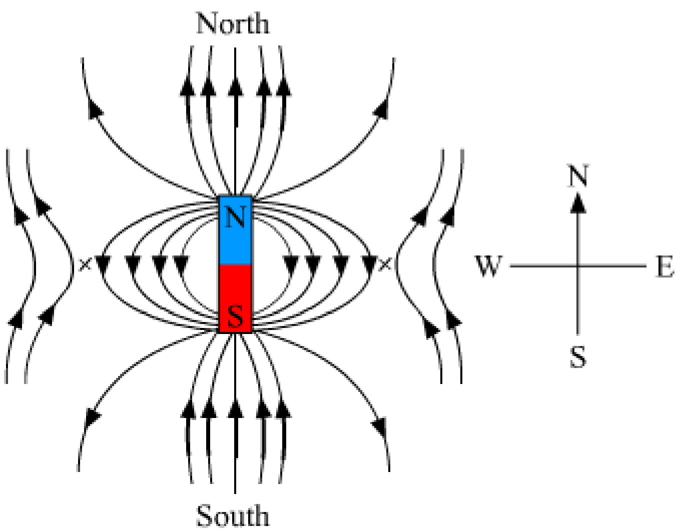
  Therefore, when a magnet is suspended, it points in the North-South direction, which is South-North for the real magnet.

  Magnetic field lines of the Earth

It is assumed that a huge bar magnet is buried within the Earth's interior, with the magnetic north pole near the geographic South Pole, and the magnetic south pole near the geographic North Pole. Since magnetic field lines originate from the magnetic north pole and end at the magnetic south pole, the Earth's magnetic field lines originate from its geographic South Pole and end at its geographic North Pole.	

Non-uniform magnetic field lines of a bar magnet placed in the magnetic meridian:

(1) Magnet placed with its north pole pointing towards the Earth's north pole

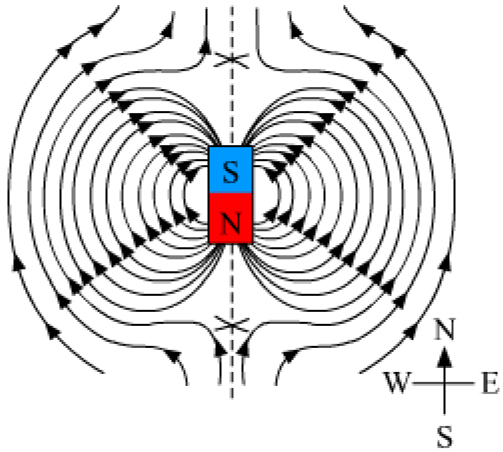


Magnetic field lines of a bar magnet when its North Pole N faces geographic North

The magnetic field lines shown above are the combined effect of (a) magnetic field of the magnet (ii) the Earth's magnetic field

The lines are curved near to magnet showing that the magnetic field lines of magnet are stronger than the earth's magnetic field at the vicinity of the magnet. When distance from the magnet increases, the Earth's magnetic field becomes stronger than the magnetic field of the magnet. Hence, magnetic field lines are parallel at distant points.

(2) Magnet placed with its south pole pointing towards the Earth's north pole.



Magnetic field lines of a bar magnet
when its North Pole N faces geographic South

In the vicinity of magnet, the magnetic field lines are curved because here the magnetic field of the magnet are stronger than the Earth's magnetic field. As we move farther away from the magnet, its field becomes weaker than the Earth's magnet field. And at distant points from the magnet these field line becomes parallel straight lines from south to north.

Neutral points: These are the points situated symmetrically on either side of a magnet where the magnetic field of the magnet and the horizontal component of the Earth magnetic field are equal in magnitude and opposite in direction.

Hence, these two magnetic fields neutralise each other at these points. Hence, when a compass needle is placed at these points, it remains unaffected and the needle rest in any direction. These points are represented by letter X in both given figures.

Do you know?

The magnetic poles of the Earth continuously change their position with time, i.e., the magnetic north pole becomes the magnetic south pole and vice-versa. This phenomenon of flipping of poles is known as magnetic reversal. It is assumed by scientists that the Earth’s magnetic field has undergone 170 such reversals in the past 100 millions years.

Permanent Magnets and Electromagnets

Amar watches his father fix an electric bell in their new house. He wonders **how a bell produces such a loud sound when its switch is pressed on**.

In this section, we will learn about the construction and working of an electric bell.

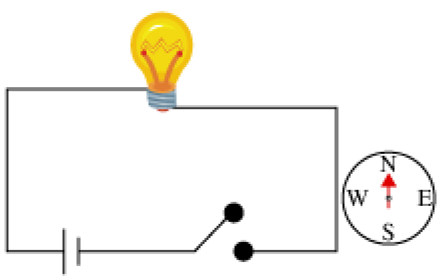
An electric bell works on the principle of electromagnetism.

Let us show you the working of an electric bell.

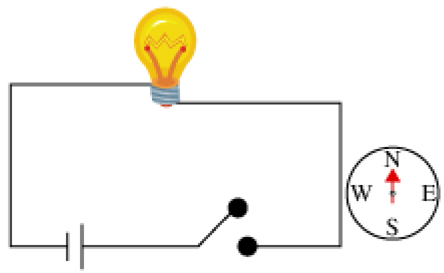
Let us perform a small experiment.

Hans Christian Oersted (1777-1851) was one of the greatest physicists of his time. Until 1820, it was believed that only natural magnets were able to possess magnetism. In 1820, Oersted suggested that a wire behaves similar to a magnet when an electric current passes through it. He was the first scientist to demonstrate the magnetic effect of current.	

Now, if you switch off the current in the previous experiment, then what would you expect to observe? **Would the needle return to its previous position? If yes, then why?**



You will observe that the needle returns to its original position. This happens because the wire carries no current when the switch is off. Hence, the phenomenon of the magnetic effect of current does not apply here.



Reverse the terminals of the cell by reversing the cell and bring the compass near the circuit again, as shown in the given figure.

Switch on the current in the circuit and observe the deflection in the compass needle. **Does the needle deflect in the same direction as in the previous case?**

You will observe that the needle is deflected in a direction opposite to that in the earlier case. This happens because the direction of current in the wire is opposite to that in the earlier case.

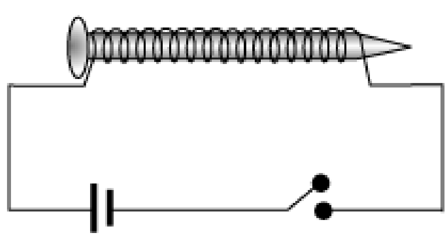
The direction of deflection of a compass needle depends on the direction of the current flowing in the wire.

The phenomenon of the magnetic effect of current is used in various fields in our day-to-day life. One such use of the magnetic effect of current is illustrated below.

Puneet visited a junkyard on a school education trip. In the junkyard, he saw the arm of a crane, with a large magnet at its bottom, move over a heap of junk and collect objects made of iron. The magnet used in a junkyard crane is not a natural or a **permanent magnet**. It is a **temporary magnet**, which is called an **electromagnet**. As its name suggests, its magnetic nature depends on the presence of an electric current.

Construction of an electromagnet

Take a long piece of insulated copper wire and an iron nail. The wire must be insulated i.e., it must be covered by plastic in order to prevent short-circuiting, which is caused by the contact of wires. Make a coil from this wire by winding it around the iron nail. Now, construct an electric circuit that consists of a cell, a switch, and the two ends of the coil, as shown in the given circuit diagram.

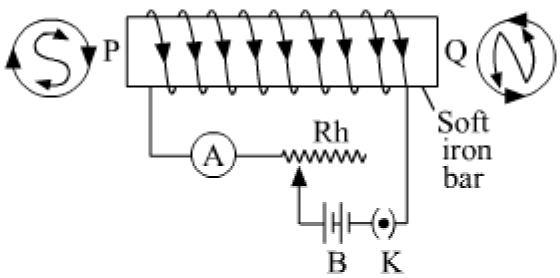


After constructing the electric circuit, switch on the current in the coil by closing the switch and bring a paper clip near one end of the nail. **What do you observe? Does the paper clip get attracted towards the end of the nail and get attached to it?**

When the switch is ON, the nail in the circuit behaves like a magnet. When a magnetic material such as an iron nail is placed within a current-carrying coil, it behaves like a magnet called **electromagnet**.

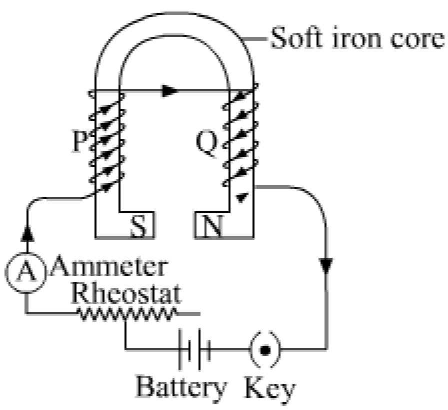
Types of an electromagnet

- **Bar-shaped or I-shaped electromagnet:** To create such an electromagnet, a thin insulated copper wire is wound in a form of a solenoid on a soft iron bar. When current passes through this wire, the bar starts behaving like an electromagnet.



I-shaped electromagnet

- **Horse-shoe or U-shaped electromagnet:** This electromagnet is constructed when a thin insulated copper wire is spirally wound on the arms of the horse-shoe shaped soft iron core. The wire is wound in such a way that when the winding is seen from both the ends, they appear to be in opposite sense on the two arms.



Horse-shoe electro-magnet

What will happen to the paper clip when you open the switch? Will it remain attached to the nail?

- **A magnetic material will act as an electromagnet till the time current continues to pass through it.**

- **When the current stops flowing, the material loses all its magnetic properties and behaves like a normal material.**

  The principle of electromagnetism is used in various devices such as electric bell, electric fan, etc.

  The strength of an electromagnet depends on the

- total number of turns in the coil of wire
- strength of the current in the coil
- characteristics of the magnetic material over which the wire is wound