JSR IAS ACADEMY

GENERAL SCIENCE
PHYSICS

Magnetism - 1

- Magnetites are **natural magnets**.
- man-made magnets are called **artificial magnets**.

Substances which are attracted by magnet are called **magnetic substances**. **Iron, cobalt, nickel** are magnetic substances.

Know Your Scientist

William Gilbert laid the foundation for magnetism and suggested that the Earth has a giant bar magnet. William Gilbert was born on 24th May 1544. He was the first man who performed the systematic research on the properties of the lodestone (magnetic iron ore) and published his findings in the influential 'De Magnete' (The Magnet).

Classification of Magnets

Magnets are classified into two types. They are: i. Natural magnets ii. Artificial magnets

Natural Magnets

- Lodestone called **magnetite (Iron oxide)** which is the ore of iron is the strongest natural magnet.
- Minerals like **Pyrrhotite (Iron Sulphide), Ferrite and Coulumbite** are also natural magnets.

DO YOU KNOW?

There are three types of iron ores. They are Hematite (69% of Iron), Magnetite (72.4% of Iron) and Siderite (48.2% of Iron). Magnetite is an oxide ore of iron with the formula Fe_3O_4. Among these ores, Magnetite has more magnetic property.

Artificial Magnets

- These are also known as man- made magnets, which are stronger than the natural magnets.
- Artificial magnets can be made in various shapes and dimensions.
- Artifi cial magnets are usually made up **of iron, nickel, cobalt, steel, etc.**
- Alloy of the metals **Neodynium and Samarium** are also used to make artifi cial magnets.

Table 2.1 Difference between natural and artificial magnets

Natural Magnets	Artificial Magnets
These are found in nature and have irregular shapes and dimensions.	These are man-made magnets. They can be made in different shapes and dimensions.
The strength of a natural magnet is well determined and difficult to change.	Artificial magnets can be made with required and specific strength.
These are long lasting magnets.	Their properties are time bound.
They have a less usage.	They have a vast usage in day to day life.

Magnetic Materials

- Magnetic materials can be categorised as magnetically hard or magnetically soft materials.
- Magnetically soft materials are easily magnetised.

- Magnetically hard materials also can be magnetised but they require a strong magnetic field to be magnetised.
- It is because materials have different atomic structure and they behave diff erently when they are placed in a magnetic field.

Based on their behaviour in a magnetic field they can be classified as below.

1. Diamagnetic
2. Paramagnetic
3. Ferromagnetic

Diamagnetic materials

- When suspended in an external uniform magnetic field they will align themselves **perpendicular** to the direction of the magnetic field.
- They have a tendency to move away from the stronger part to the weaker part when suspended in a non-uniform magnetic field.
- They get magnetised in a direction opposite to the magnetic field.
- Examples for diamagnetic substances are **bismuth, copper, mercury, gold, water, alcohol, air and hydrogen.**
- Magnetic character of these substances is not aff ected by the external temperature.

Paramagnetic materials

- When suspended in an external uniform magnetic fi eld they will align themselves **parallel** to the direction of the magnetic field.
- They have a tendency to move from the weaker part to the stronger part when suspended in a non-uniform magnetic field.
- They get magnetised in the direction of the field.
- Examples for paramagnetic substances are **aluminium, platinum, chromium, oxygen, manganese, solutions of salts of nickel and iron.**
- Magnetic character of these substances is affected by the external temperature.

Ferromagnetic materials

- When suspended in an external uniform magnetic field they will align themselves **parallel** to the direction of the magnetic field.
- It has a tendency to move quickly from the weaker part to the stronger part when suspended in a non-uniform magnetic field.
- They get strongly magnetised in the direction of the field.
- Examples for ferromagnetic substances **are iron, cobalt, nickel, steel and their alloys.**
- Magnetic character of these substances is affected by the external temperature. When they are heated they become para magnetic.

The temperature, at which the ferromagnetic material becomes paramagnetic is called the curie temperature.

Artificial Magnets

- These are generally made by magnitising iron or steel alloys electrically.
- These magnets are also produced by stroking a magnetic material with magnetite or with other artificial magnets.
- artificial magnets are classified as permanent magnets or temporary magnets.

Temporary Magnets

- Temporary magnets are produced with the help of an external magnetic field.
- They lose their magnetic property as soon as the external magnetic field is removed.
- They are made from soft iron.
- Soft iron behaves as a magnet under the influence of an external magnetic field produced in a coil of wire carrying a current.
- But, it loses the magnetic properties as soon as the current is stopped in the circuit.
- Magnets used in electric bells and cranes are the examples of temporary magnets.

DO YOU KNOW?

Magnetisation is a process in which a substance is made a permanent or temporary magnet by exposing it to an external magnetic field. This is one of the methods to produce artificial magnets.

Permanent Magnets

- ❖ Permanent magnets are artificial magnets that retain their magnetic property even in the absence of an external magnetic field.
- ❖ These magnets are produced from substances like hardened steel and some alloys.
- ❖ The most commonly used permanent magnets are made of **ALNICO (An alloy of aluminium, nickel and cobalt).**
- ❖ Magnets used in refrigerator, bar magnet, speaker magnet, fridge magnet and magnetic compass are some familiar examples of a permanent magnet.
- ❖ Neodymium magnets are the strongest and the most powerful magnets on the Earth.

DO YOU KNOW?

Alnico cow magnet is used to attract sharp iron wire and other iron objects that may be ingested by animals while grazing thereby causing damage to their digestive tract.

Earth's Magnetism

DO YOU KNOW?

The most powerful magnet in the universe is actually a neutron star called magnetar (magnetic neutron star) located in the Milky Way Galaxy. The diameter of the magnetar is 20 kilometer and its mass is 2 to 3 times that of the Sun. Its magnetic field is so enormous and lethal that it is capable of absorbing all the iron atoms from the bloodstream (hemoglobin) of a living body even if it is positioned at a distance of 1000 km from it.

The line joining these magnetic poles is called the magnetic axis.

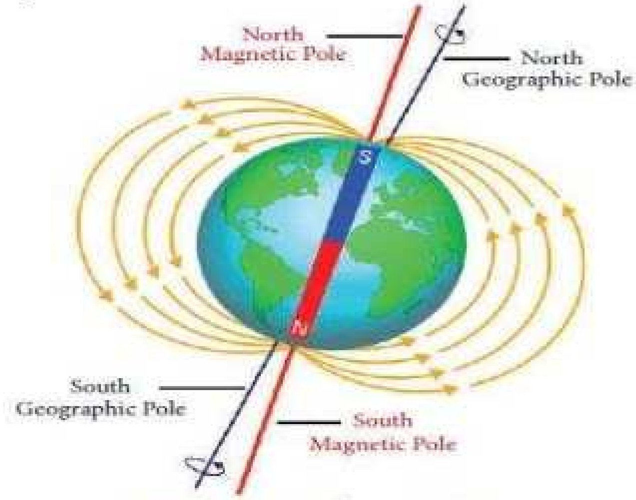


Figure 2.5 Earth as a magnet

- ❖ The magnetic axis intersects the geographic north pole at a point called the north geomagnetic pole or northern magnetic pole.
- ❖ It intersects the geographic south pole at a point called the south geomagnetic pole or southern magnetic pole.
- ❖ The magnetic axis and the geographical axis (axis of rotation) do not coincide with each other.
- ❖ The magnetic axis of the Earth is inclined at an angle of about 10° to 15° with the geographical axis.

However, some important factors, which may be the cause of the Earth's magnetism, are as follows.

- ❖ Masses of magnetic substances in the Earth
- ❖ Radiations from the Sun
- ❖ Action of the Moon

However, it is believed that the Earth's magnetic field is due to the molten charged metallic fluid inside the Earth's surface with a core of radius of about 3500 km compared to the Earth's radius of 6400 km.

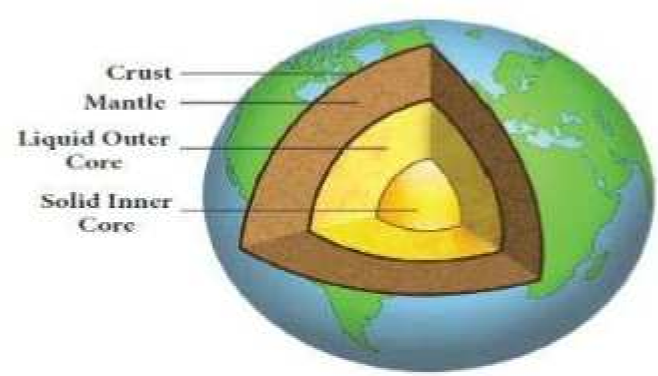


Figure 2.6 Core of the Earth

Pigeons have extraordinary navigational abilities. It enables them to find their way back home even if you take them to a place where they have never been before. The presence of magnetite in their beaks enables them to sense the magnetic field of the Earth. Such a magnetic sense is called **magneto-reception.**

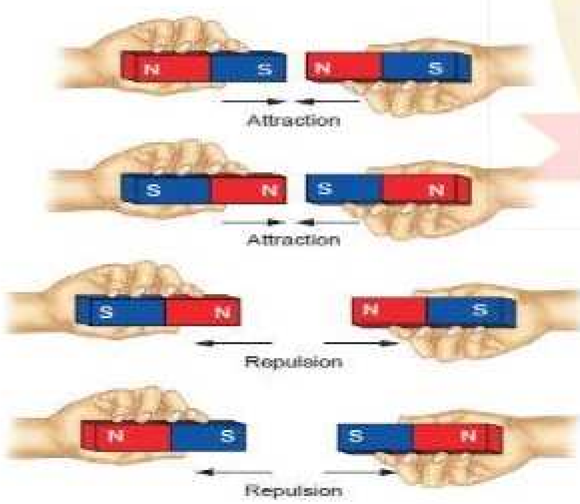
Earth's Magnetic Field

The magnitude of the magnetic field strength at the Earth's surface ranges from 25 to 65 micro tesla.

Earth's magnet is 20 times more powerful than a fridge magnet.

Magnetic Poles

The attractive force of the magnet is very large near the two ends. These two ends are called its poles.

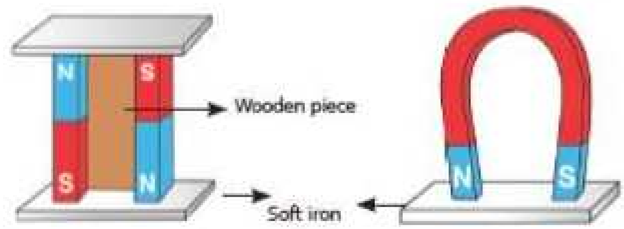


Unlike poles (S-N, N-S) attract each other. Like Poles (N-N, S-S) repel each other.

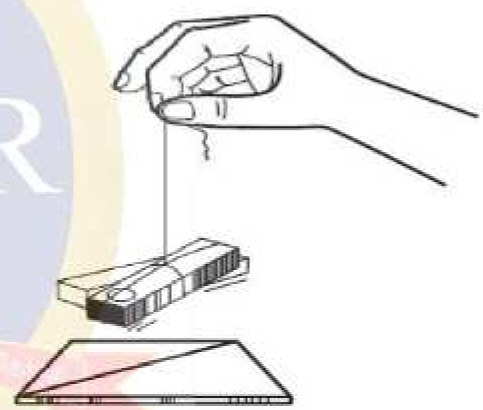
The magnetic properties of a magnet will be removed from it by the following ways.

Placing the magnet idle for a long time.
Passing a variable current in a coil that encloses the magnet.
Magnets lose their properties if they are **heatedor dropped from a height or hit with a hammer**
Improper storage of the magnet.

Magnets lose their properties when they are placed near Cellphone, Computer, DVDs. These objects will also get affected by magnetic field.



Finding directions with a magnet



- A freely suspended magnet always comes to rest in north-south direction.
- The end of the magnet that points to the north is called the **North Pole.** The end that points to the south is called the **South Pole.**

Magnetic compass

A compass is an instrument which is used to find directions.

- The compass has a magnetic needle that can rotate easily.
- The marked end of the needle is the North Pole of the magnet.

Can you use magnetic compass to fi nd west direction? Ask your teacher to help you in using magnetic compass.

DO YOU KNOW? The directive property of magnets has been used for centuries to find directions. Around 800 years ago, the Chinese discovered that a suspended lode stone stops in the north-south direction. Chinese used these lode stones to find directions.

The navigators of that country used to keep a piece of lode stone suspended in their boats and during a storm or mist, they used the lode stone to locate directions.

How does the electromagnetic train work?

- Electromagnets are used in Electromagnetic train. Electromagnets are magnetised only when current flows through them.
- When the direction of current is changed the poles of the electromagnets are also changed. Like poles of the magnets which are attached at the bottom of the train and rail track repel each other. So, the train is lifted from the track up to a height of 10 cm.
- This train also moves with the help of the magnets attached on the sides of track and the magnets fitted at the bottom sideway of the train. By controlling the current we can control the magnets and movement of the train.
- As there are no moving parts, there is no friction. So, the train can easily attain a speed of 300 km per hour. These trains are capable of running up to 600 km/ hour.
- They do not make any noise. They require less energy and they are eco-friendly.
- Even though, many countries have taken effort to use these trains, such trains are used for public transport only in China, Japan and South Korea.

Magnetic flux

Magnetic flux is the number of magnetic field lines passing through a given area

It is denoted by ϕ and its unit is weber (Wb).

The number of magnetic field lines crossing unit area kept normal to the direction of field lines is called magnetic flux density.

Its unit is Wb/m2

DO YOU KNOW? Some sea turtles (loggerhead sea turtle) return to their birth beach many decades after they were born, to nest and lay eggs. In a research, it is suggested that the turtles can perceive variations in magnetic parameters of Earth such as magnetic field intensity and remember them. This memory is what helps them in returning to their homeland.

Magnetic Field Lines

- A magnetic field line is defined as a curve drawn in the magnetic field
- They start at north pole and ends at south pole.
- the arrow mark indicates the direction of magnetic field at points
- the magnetic field at a point is tangential to the magnetic field lines.

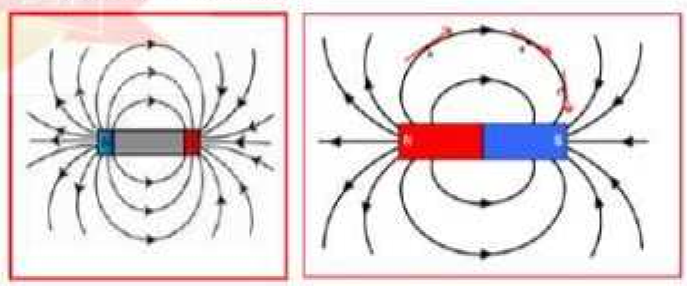


Figure 5.2 Magnetic field lines

Properties of magnetic lines of force

- Magnetic lines of force are closed, continuous curves,extending through the body of the magnet
- Magnetic lines of force start from the North Pole and end at the South Pole.
- Magnetic lines of force never intersect.
- They will be maximum at the poles than at the equator.

- The tangent drawn at any point on the curved line gives the direction of magnetic field.

Magnetic effect of current

- It was on 21st April 1820, Hans Christian Oersted, a Danish Physicist was giving a lecture.
- Accidentally, he noticed the needle of the magnetic compass that was on the table. It deflected whenever he switched on and the current was flowing through the wire.
- The compass needle moved only slightly, so that the audience didn't even notice. But, it was clear to Oersted that something significant was happening.
- He conducted many experiments to find out a startling effect, the magnetic effect of current.

- Oersted aligned a wire XY such that they were exactly along the North-South direction. He kept one magnetic compass above the wire at A and another under the wire at B.
- When the circuit was open and no current was flowing through it, the needle of both the compass was pointing to north.
- Once the circuit was closed and electric current was flowing, the needle at A pointed to east and the needle at B to the west as shown in
- This showed that current carrying conductor produces magnetic field around it.

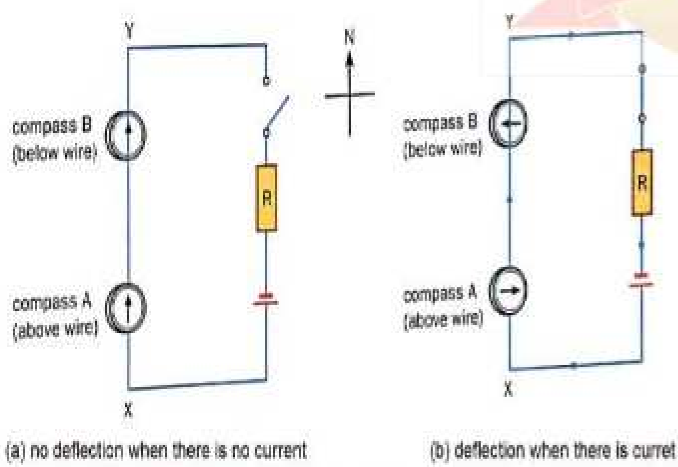


Figure 5.5 Current produces magnetic field

Right hand thumb rule

- The direction of the magnetic lines around a current carrying conductor can be easily understood using the right hand thumb rule.
- Hold the wire with four fingers of your right hand with thumbs-up position.
- If the direction of the current is towards the thumb then the magnetic lines curl in the same direction as your other four fingers
- This shows that the magnetic field is always perpendicular to the direction of current.

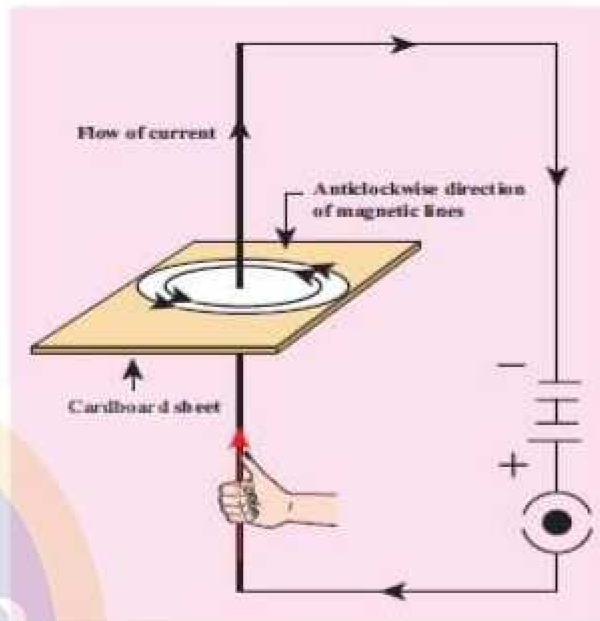


Figure 5.6 Right hand thumb rule

The strength of the magnetic field at a point due to current carrying wire depends on:

- the current in the wire,
- distance of the point from the wire,
- the orientation of the point from the wire and
- the magnetic nature of the medium.
- The magnetic field lines are stronger near the current carrying wire and it diminishes as you go away from it.

Force on a current carrying conductor in a magnetic field

H.A.Lorentz found that a charge moving in a magnetic field, in a direction other than the direction of magnetic field, experiences a force. It is called the magnetic Lorentz force.

In 1821, Michael Faraday discovered that a current carrying conductor also gets deflected when it is placed in a magnetic field.

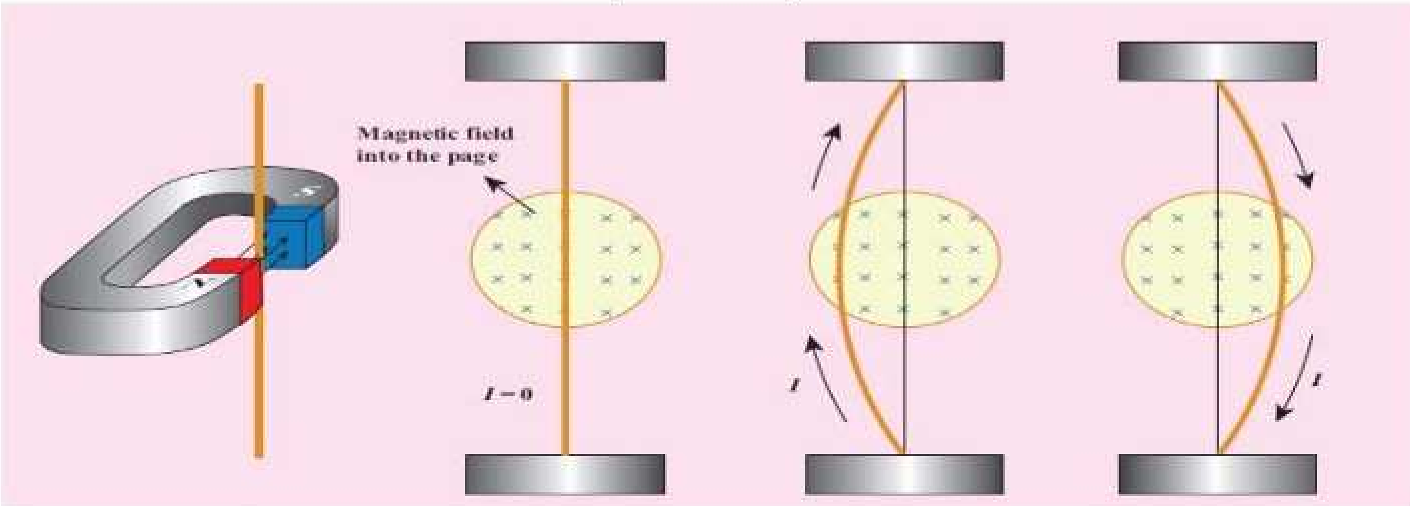


Figure 5.7 Deflection of current carrying wire in magnetic field

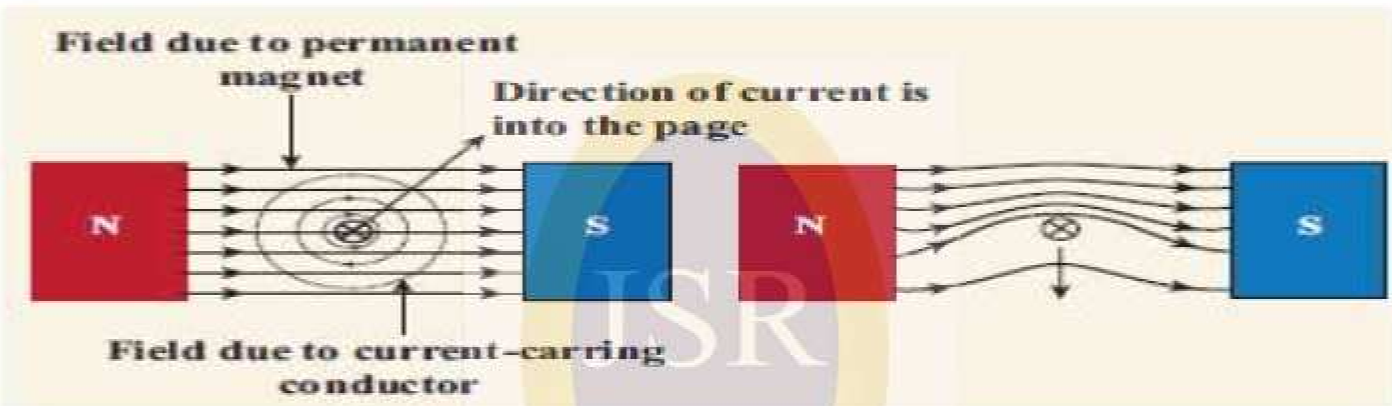


Figure 5.8 Force on a current carrying conductor kept in magnetic field

If a current, I is flowing through a conductor of length, L kept perpendicular to the magnetic field B, then the force F experienced by it is given by the equation,

F = I L B

- ❖ When the conductor is perpendicular to the magnetic field, the force will be maximum (=BIL).
- ❖ When it is parallel to the magnetic field, the force will be zero.
- ❖ The force is always a vector quantity.
- ❖ A vector quantity has both magnitude and direction.

Left hand Rule

The direction is often found using what is known as Fleming's Left hand Rule (formulated by the scientist John Ambrose Fleming).

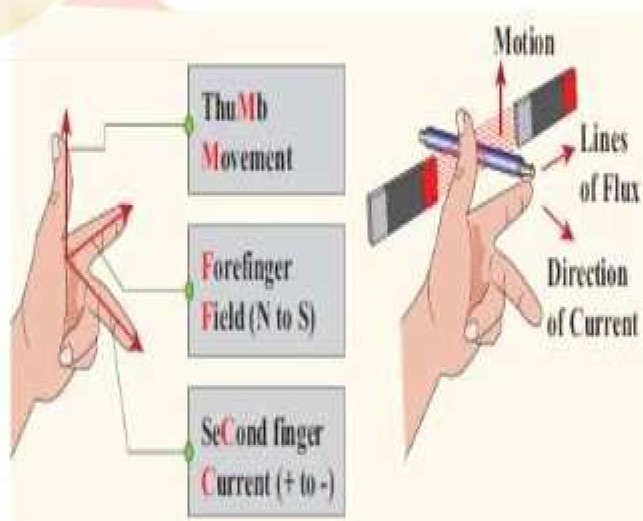


Figure 5.9 Fleming's left hand rule

The law states that while stretching the **three fingers of left hand** in perpendicular manner with each other,

- if the direction of the current is denoted by the middle finger of the left hand
- the second finger is for direction of the magnetic field,
- the thumb of the left hand denotes the direction of the force or movement of the conductor.

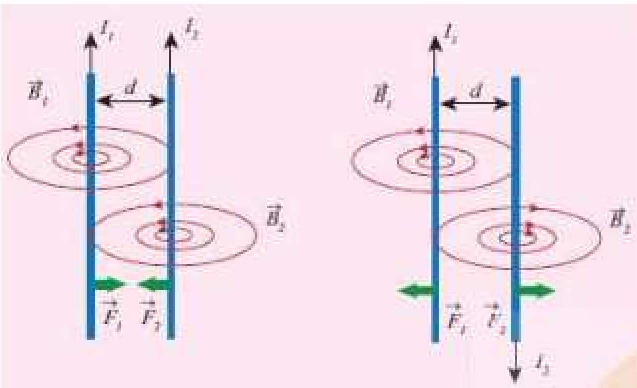


Figure 5.10 Attractive and repulsive force on current carrying wires

A conductor of length 50 cm carrying a current of 5 A is placed perpendicular to a magnetic field of induction 2×10^{-3} T. Find the force on the conductor.

Solution:

Force on the conductor = ILB

$= 5 \times 50 \times 10^{-2} \times 2 \times 10^{-3}$

$= 5 \times 10^{-3}$ N

A current carrying conductor of certain length, kept perpendicular to the magnetic field experiences a force F. What will be the force if the current is increased four times, length is halved and magnetic field is tripled?

Solution:

F = I L B = (4I) × (L/2) × (3 B) = 6 F

Therefore, the force increases six times.