M A G N E T I S M

This is a piece of material that attracts other materials.
Magnetism is the force exerted by a magnetic field.

Magnetic material:
This is a material that can be attracted or repelled by a magnet e.g. steel, iron e.t.c.
Non-magnetic material:
This is a material that can not be repelled or attracted by a magnet e.g. plastic, rubber, paper etc.

There are different magnetic materials and non-magnetic materials and these include the following;
Ferro magnetic materials:
These are magnetic materials that are strongly attracted by a magnet.
Ferro magnetic materials are capable of being made into a magnet and retain magnetic properties when the external magnetic field is removed.

Paramagnetic materials:
These are materials that are weakly attracted by a strong magnet.
A paramagnetic material does not retain the magnetic properties when the external field is removed.

Diamagnetic materials:
These are magnetic materials that are weakly repelled by a strong magnet.
A diamagnetic material does not retain the magnetic properties when the external field is removed.

The table below shows examples of different materials;

Ferro magnetic	Paramagnetic	Diamagnetic	Non-magnetic
Cobalt Iron Nickel Steel	Magnesium Lithium	Zinc Silver Gold	Rubber Plastic Leather Paper Copper Brass

POLARITY OF A MAGNET:

A pole of a magnet is a region on a magnet where the magnetic force is strongest.
Poles of a magnet are found at the ends of a magnet and they occur in pairs of equal strength.
A magnet has two poles namely;

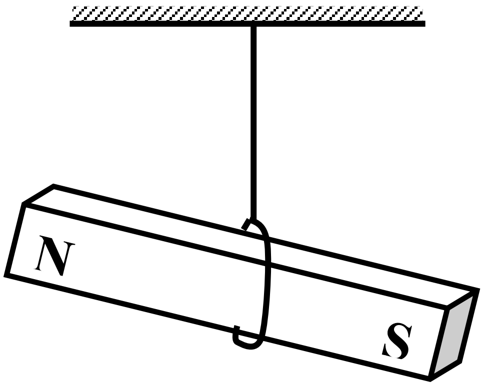
- North Pole
- South Pole.

LAW OF MAGNETISM:
It states that unlike poles attract and like poles repel each other.

Experiment to determine the polarity of a magnet

(a) Suspension method:

Suspend an unmarked marked magnet with the help of a thread so that it can rotate freely.
Wait until the magnet comes to rest.



It is observed that the magnet comes to rest in the North-South direction.
The end pointing in the earth's geographical north (northern hemisphere) is the North pole (N).
The end pointing in the earth's geographical south (southern hemisphere) is the South pole (S)

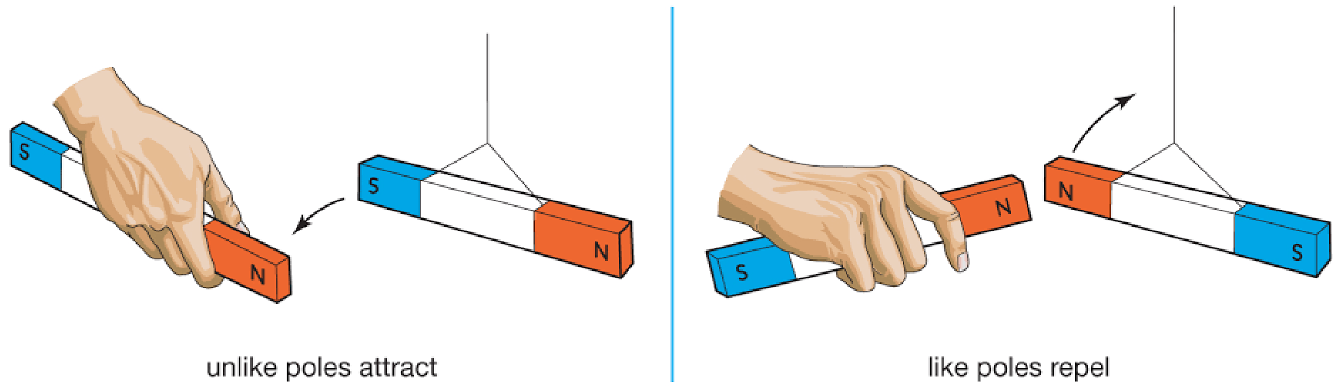
NOTE:

Since the earth is also a magnet, its north pole is in the southern hemisphere and its south pole is in the northern hemisphere.

(b) Using a magnet of known poles:

A magnet whose poles are known is brought near the ends of another suspended magnet whose poles are unknown.

Observation:



If there is repulsion between the ends of the two magnets, then the poles are like.
If there is attraction between the ends of the two magnets, then the poles are unlike.

NOTE: Repulsion is the only sure way to test for the polarity of a magnet since attraction can occur either between magnets or between a magnet and un-magnetised material.

Properties of a magnet:

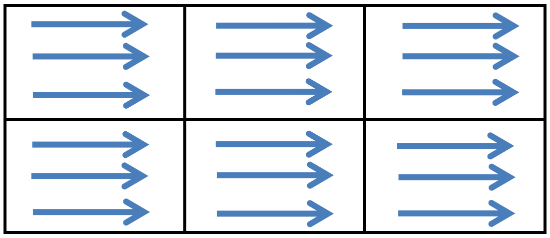
- Unlike poles attract while like poles repel each other.
- The attraction power of a magnet is strongest at the poles.
- When a magnet is freely suspended, it always come to rest in the North-South direction.
- Magnets attract certain materials e.g. steel.

Experiment to show that attraction power is strongest at the poles.

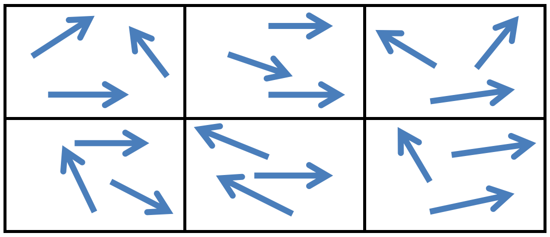
- Dip a bar magnet into iron fillings and observe.
- It is observed that most of the iron fillings concentrate/ cluster around the magnetic poles than in the middle.

DOMAIN THEORY OF MAGNETISM

The domain theory of magnetism states that all magnetic materials are made up of tiny magnets called dipoles which are divided into regions called domains.
In a magnetized magnetic material, the dipoles face in the same direction.



In an un-magnetized magnetic material, the dipoles face in different directions.



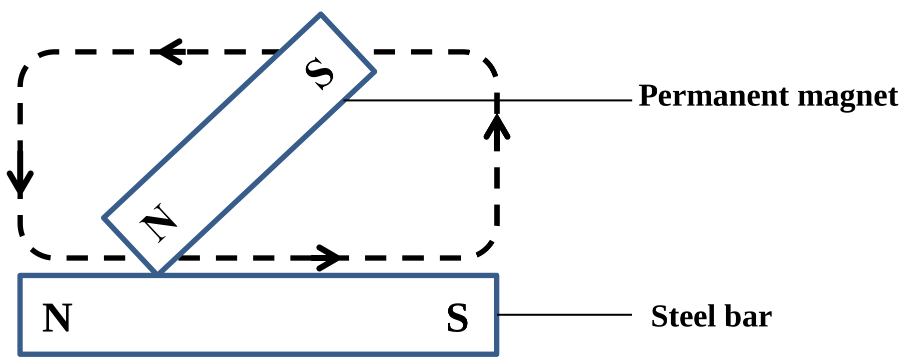
MAGNETIZATION

This is the process of making a magnet.
This process helps to arrange the dipoles of a ferromagnetic material to face in one direction.

Methods of magnetization:
The methods include;

- Single touch/stroke method.
- Double or divided touch/stroke method
- Electrical method
- Hammering
- Induction method

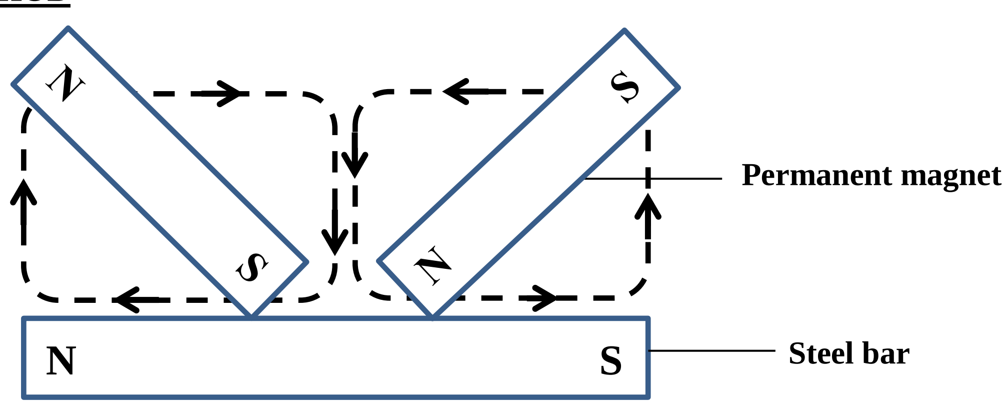
SINGLE TOUCH/STROKE METHOD



- The steel bar is stroked from one end to another several times in the same direction using one pole of a permanent magnet.
- At the end of each stroke the permanent magnet is lifted high above the steel bar
- The end of the steel bar where the magnet finishes stroking acquires an opposite pole to that of the stroking pole.

Note: The disadvantage of this method is that it produces a magnet with one pole nearer the end of the steel bar than the other.

DOUBLE TOUCH METHOD



- The steel bar is stroked using two unlike poles of permanent magnets simultaneously from the centre outwards for several times.
- At the end of each stroke, the permanent magnets are lifted high above the steel bar.
- The ends of the steel bar where the magnets finish stroking acquires opposite poles to that of the stroking pole.

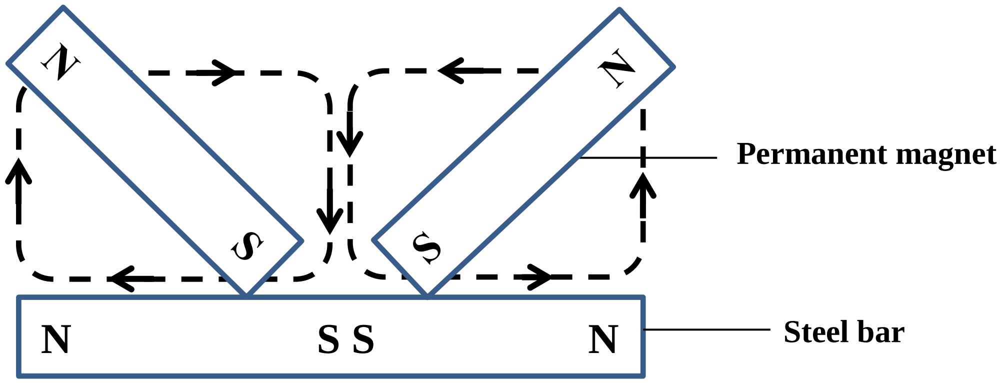
Note: Lifting the permanent magnet high above the steel bar helps to avoid cancellation of arrangement of dipoles already made.

Consequent poles:

Consequent poles of a magnet are double like poles both at the centre and at the ends of a magnetic material.

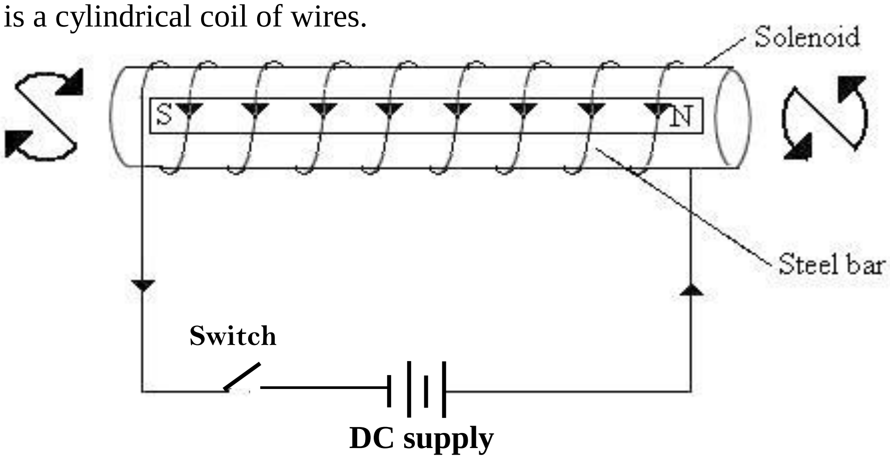
Consequent poles are obtained when a steel bar is stroked using two like poles of permanent magnets from the centre outwards.

A magnet with consequent poles never comes to rest if it is suspended.



ELECTRICAL METHOD

A solenoid is a cylindrical coil of wires.



- A steel bar is placed inside a solenoid connected to a direct current supply.
- Current is switched on for a short time and then switched off.
- The steel bar is magnetized and the polarity of the magnet formed depends on the direction of current.
- On looking at one end of the solenoid, if current is flowing in the anticlockwise direction then that end is a North pole and if current is flowing in the clockwise direction then that end is a South pole.

NOTE:

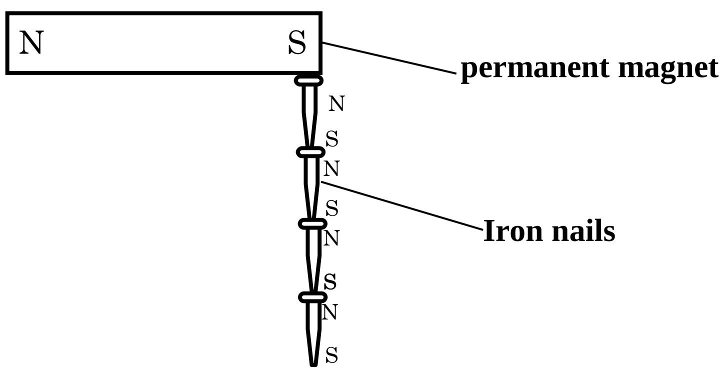
- Since direct current flows in one direction, the dipoles of the steel bar are arranged so as to face in the same direction.
- If Alternating current was used, the arrangement of the dipoles of the steel bar would be disorganized so that they don't face in the same direction.

HAMMERING

A steel bar is hammered several times while facing in the North-South direction. During the hammering, the dipoles are arranged to face in one direction.

INDUCED MAGNETISM

Magnetic induction is the process by which a magnetic material becomes magnetized by bringing near or in contact with the pole of a permanent magnet.
A piece of un-magnetized steel/iron becomes magnetized when it is placed in contact with the pole of a permanent magnet for some time. This is magnetization by induction because magnetic properties are induced in steel/iron by the permanent magnet.
The end of the magnetic material nearest the pole of a permanent magnet an opposite pole.



In the above diagram, the nails form a magnetic chain. The south pole of the permanent magnet induces a north pole at the tip of the first nail and south pole at the bottom. The process continues.
The dipoles in the iron nails are arranged to face in the same direction by the permanent magnet.
However, induced magnetism is short lived i.e. it doesn't last for a long period of time.

Magnetic saturation:

Magnetic saturation is a point reached where a magnetic material cannot be magnetized any more.
At this point, all the tiny magnets (dipoles) are arranged in the same direction.

DEMAGNETIZATION

This is a process by which a magnet loses its magnetism.
During this process, the order of the tiny magnets (dipoles) is so disorganized such that the dipoles face in different directions.

Methods of demagnetization:
Magnets are demagnetized in the following ways;
Heating:
The magnet is heated until it becomes red-hot and then cooled while resting in the East-West direction.
The disorganizes the arrangement of the magnetic dipoles.

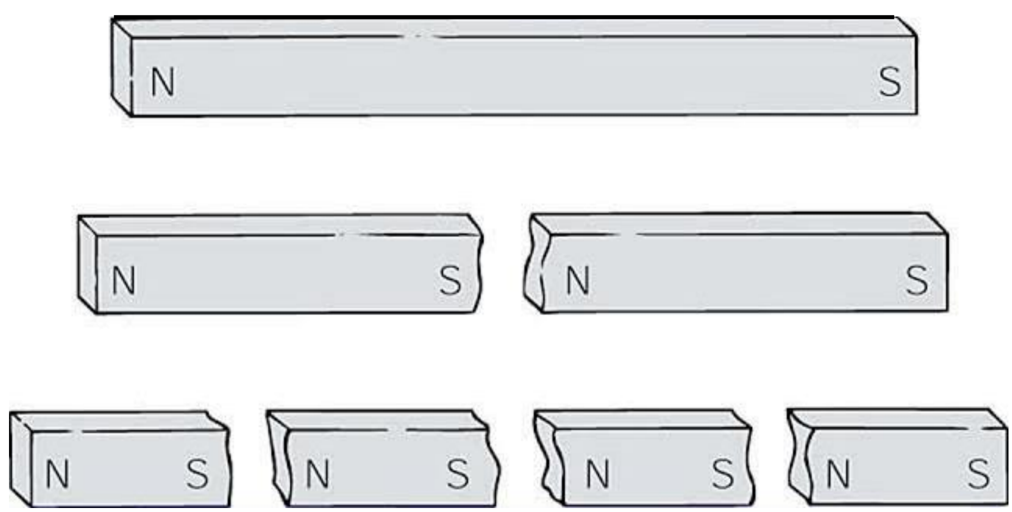
Hammering:
The magnet is hammered several times while resting in the East-West direction.

Using alternating current:
A magnet is placed in a solenoid connected to an alternating current supply while resting in the East-West direction.
Switching on and off and then removing the magnet.
The magnet loses its magnetism since A.C current disorganizes the arrangement of the dipoles.

Note: During demagnetization, the magnet is rested in the East – West direction so that it doesn't retain some magnetism due to the earth's magnetic field.
Other methods of demagnetization include dropping a magnet.

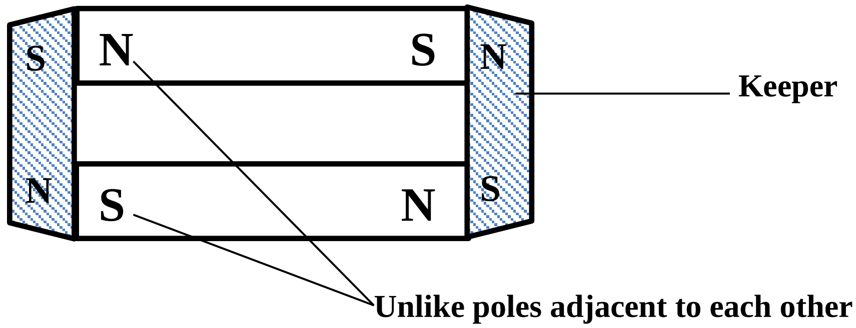
BREAKING A MAGNET

When a magnet is broken into two or more pieces, each broken piece has a North pole and South pole.
Therefore, each piece is a complete magnet.



STORING MAGNETS

Magnets tend to become weaker with time due to **self-demagnetization** due to repulsion between free like poles near the ends. This disorganizes the arrangement of the dipoles in magnets.
To prevent self-demagnetization, magnets are stored in pairs with their unlike poles adjacent to each other with small pieces of soft iron called **keepers** placed across their ends.
The keepers are magnetized by induction thus forming a closed loop of magnets with no free exposed poles. This eliminates self-demagnetization.



SOFT AND HARD MAGNETIC MATERIALS

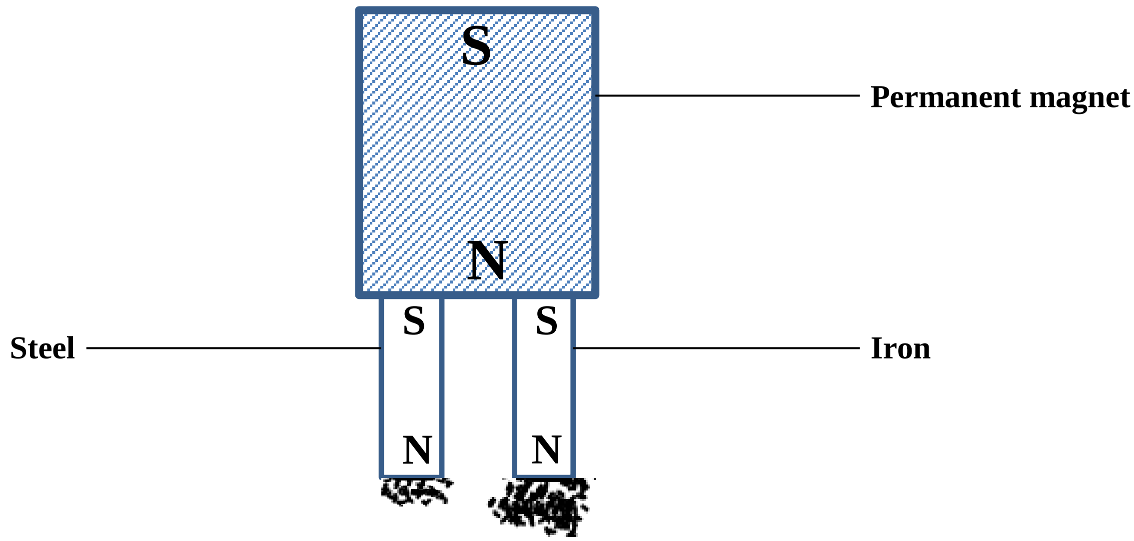
SOFT MAGNETIC MATERIALS:
These are magnetic materials which are easily magnetized but do not retain their magnetism for a long period of time. E.g. Iron, Nickel.
They are used in making of temporary magnets e.g. in electric bells, relays, magnetic keepers and transformer cores.

HARD MAGNETIC MATERIALS:
These are magnetic materials which are not easily magnetized but retain their magnetism for a long period of time. E.g. steel.
They are used in making of permanent magnets e.g. in loud speakers, dynamos, telephone receiver etc.

Magnetic properties of iron:
It is easily magnetized.
It is easily demagnetized.
It keeps its magnetism for a short period of time.

Magnetic properties of steel:
It is not easily magnetized.
It is not easily demagnetized.
It keeps its magnetism for a long period of time.

Experiment to distinguish between the properties of steel and iron.



- Un-magnetized strips of Iron and Steel are placed side by side in contact with the pole of a magnet.
- Both strips are then dipped in iron fillings.

Observation:

- More iron fillings are attracted to the iron strip than the steel strip indicating that iron is easily magnetized than steel.
- On removing the permanent magnet, almost all iron fillings on iron fall off and very few fall from steel indicating that iron is easily demagnetized than steel.

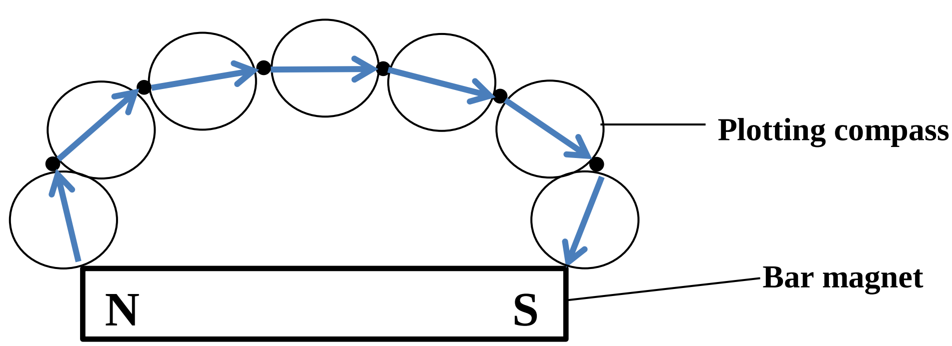
MAGNETIC FIELDS

A magnetic field is the region around a magnet where a magnetic force is experienced.
Magnetic field is stronger near the poles but weaker further away from the poles.
Magnetic fields are represented by magnetic field lines.

Magnetic field lines: These are lines which show the strength of a magnetic force.
Magnetic flux: This is the number of magnetic field lines that pass a given region.

DETERMINING MAGNETIC FIELD PATTERN

(i) Using a plotting compass:



- A bar magnet is placed on a piece of paper.
- The outline of the bar magnet is marked and its poles indicated on the paper.
- A plotting compass is brought near the North pole of the magnet.
- The direction pointed by the North pole of the plotting compass is marked with a pencil dot.
- The compass is moved onto the dot and a second dot is made.
- The process is continued until the south pole of the magnet is reached.
- The dots are joined by a smooth curve which represents a magnetic field line.

(ii) <u>Using iron fillings</u>:

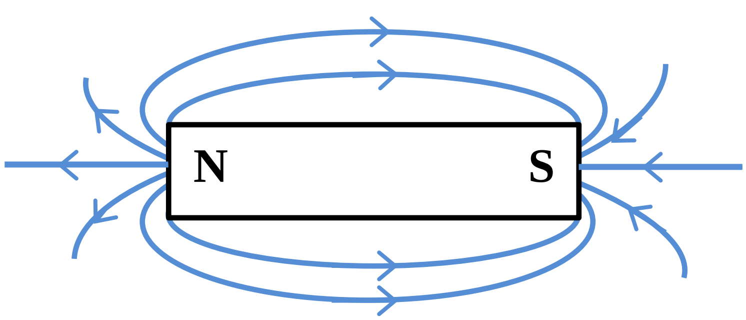
- A bar magnet is placed on a table and then covered with a smooth paper.
- Iron fillings are sprinkled all over the paper.
- The paper is gently tapped.
- The iron fillings arrange themselves as shown above.

<u>Properties of magnetic field lines</u>:

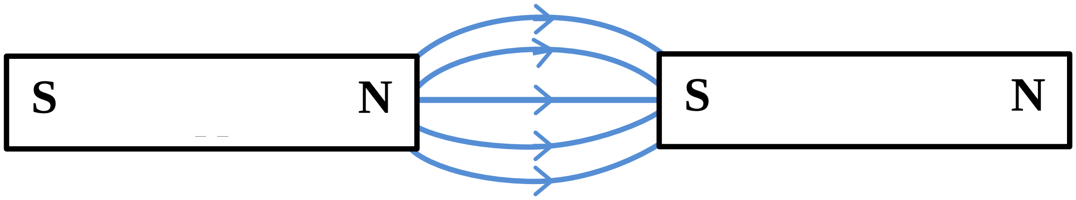
They move from North pole to South pole.
They do not cross each other.
They are closer at the poles.
They can pass through a non-magnetic material.
They all have the same strength.
The number of magnetic field lines show the strength of a magnet.

MAGNETIC FIELD PATTERNS

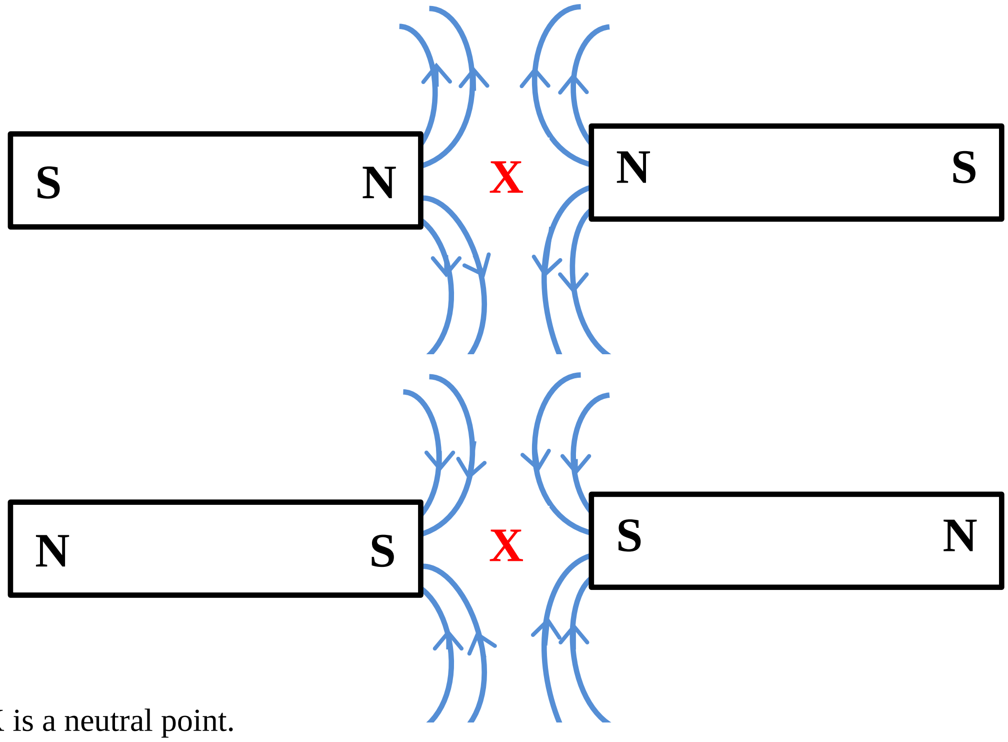
(a) <u>Isolated bar magnet</u>:



(b) **<u>Two magnets with unlike poles facing each other</u>:**



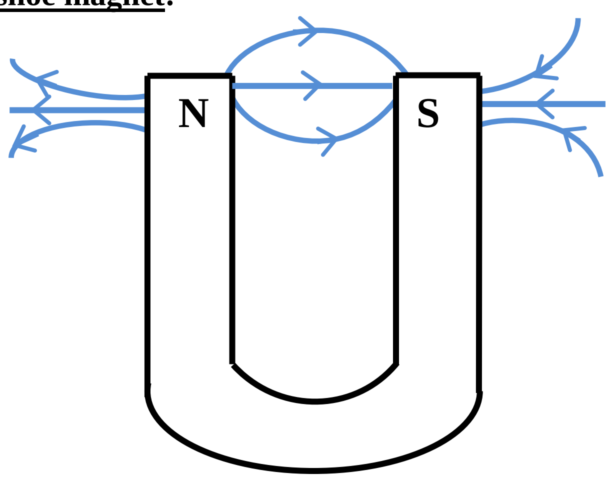
(c) **<u>Two magnets with like poles facing each other</u>:**



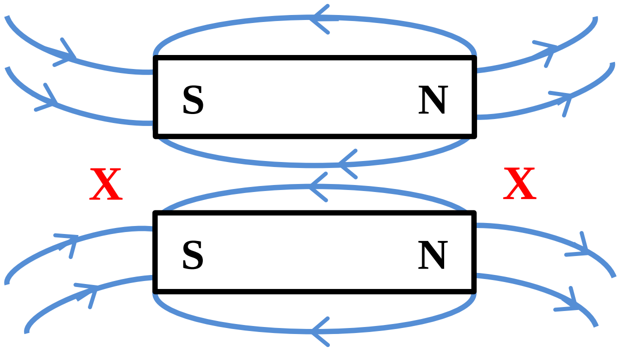
Where X is a neutral point.

<u>Neutral point</u>: This is a point in a magnetic field where the resultant magnetic force is zero.

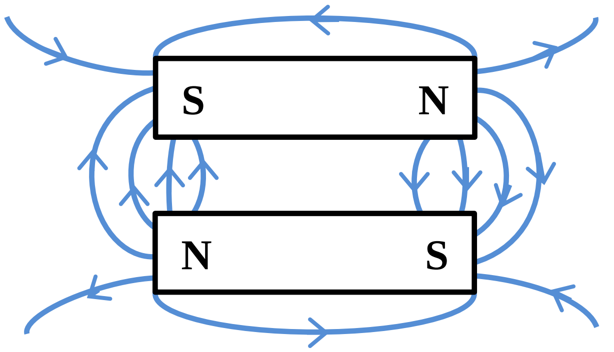
(d) **<u>Horse shoe magnet</u>:**



(e) **Two bar magnets placed parallel with same poles facing each other:**



(f) **Two bar magnets placed parallel with same poles facing each other:**

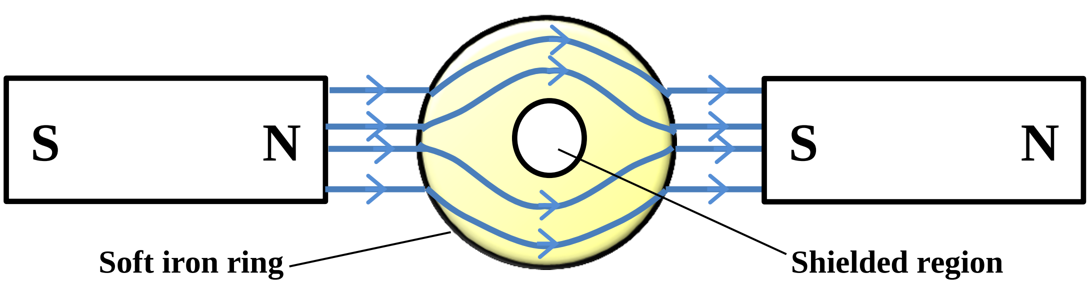


MAGNETIC SHIELDING (SCREENING)

This is the creation of a magnetically neutral space or region in the neighbourhood of the magnetic field irrespective of the strength of the field.

Iron has the ability of concentrating all magnetic field lines from the surrounding through itself because it is more permeable to magnetic fields than the surrounding air.

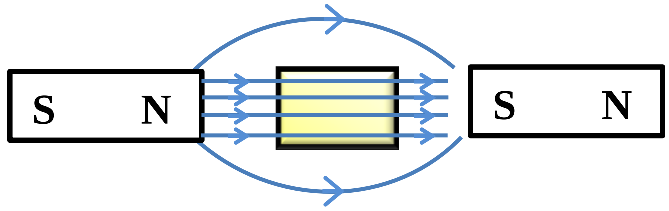
- In magnetic shielding/screening, a soft iron ring is used since it concentrates all magnetic field lines to pass through its walls and no magnetic flux passes the surrounding of the iron ring.



The space inside the ring is said to be shielded from magnetic fields.
This property of iron is used to protect delicate instruments which are easily affected by magnetic fields.
Magnetic screening can be applied in;

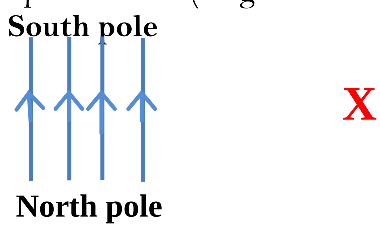
- Non digital watches.
- Television tubes or cathode ray tubes.

Note: if a soft iron box is used, the magnetic field lines just pass directly through it.



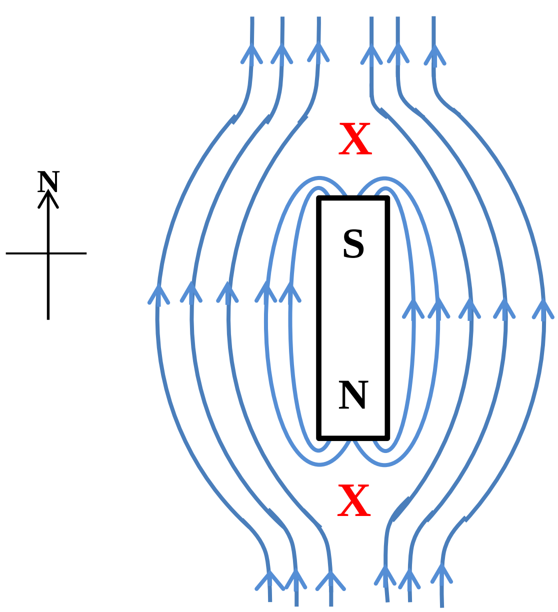
EARTH'S MAGNETIC FIELD

A freely suspended bar magnet always comes to rest pointing in the North-South direction. This is due to the magnetic field of the earth.
The earth behaves as though it contains a short bar magnet inclined at a small angle to its axis of rotation with its South Pole in the northern hemisphere (geographic North) and the North Pole pointing to the Southern hemisphere (geographic South).
The earth's magnetic field lines are made up of parallel lines running from the geographical south (magnetic North pole) to the geographical north (magnetic South pole).



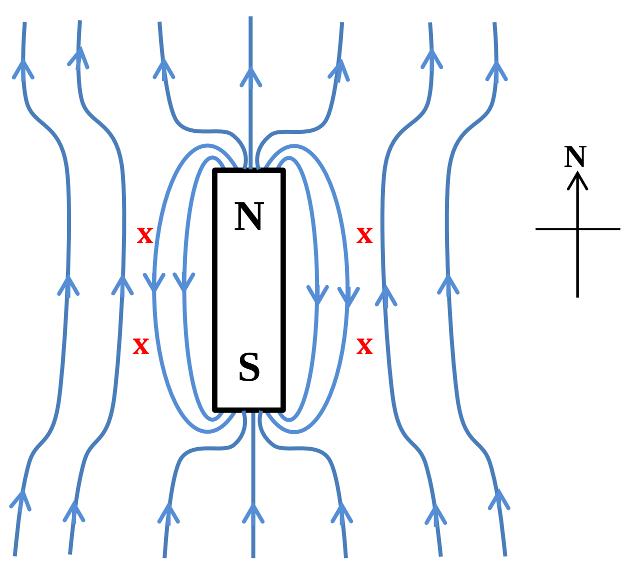
<u>Effect of magnetic field of a bar magnet on the earth's magnetic field</u>:

(a) North pole of a bar magnet pointing in the earth's geographical south.

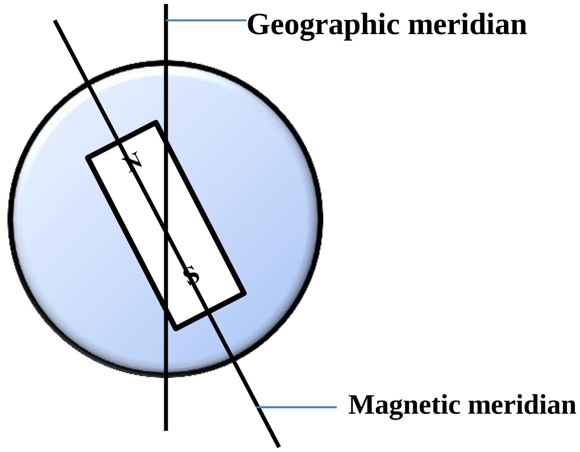


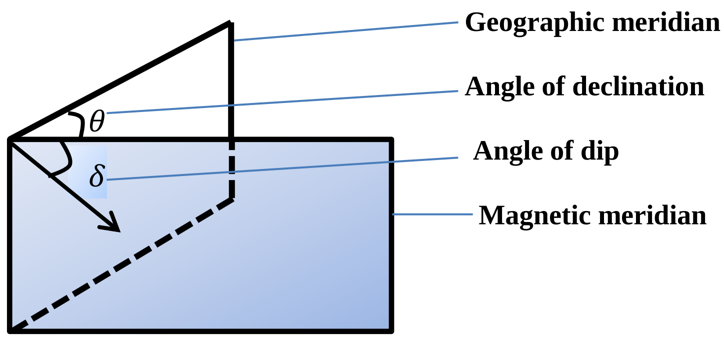
X-neutral point

(b) North pole of a bar magnet pointing in the earth's geographical North.



Terms used in the earth's magnetic field:





Geographic meridian:
This is the vertical plane which passes through the earth's geographical poles.

OR

This is a vertical plane passing through the geographical axis of the earth.

Magnetic meridian:
This is the vertical plane in which passes through the poles of a freely suspended bar magnet in the earth's magnetic field.

OR

This is a vertical plane passing through the earth's magnetic axis.

Angle of declination (θ):
This is the angle between the geographic meridian and the magnetic meridian.

Angle of dip/inclination (δ)
This is the angle between the earth's horizontal surface and the earth's magnetic field at a point.
The angle of dip varies from place to place i.e. it is 0^0 at the equator and 90^0 at the geographic North pole of the earth.

Magnetic axis: This is an imaginary line passing through poles of a freely suspended bar magnet in the earth's magnetic field.
Geographic axis: This is an imaginary line passing through the geographical poles of the earth.

EXERCISE:

1. Describe two methods of magnetizing a steel rod
2. Compare magnetic properties of steel and iron
3. Explain why a magnetic material is attracted by a magnet
4. Explain why iron filings are not suitable for plotting lines of force of a weak magnet field
5. Explain why soft iron can not be used to make permanent magnet
6. Describe how you would verify the basic law of magnetism.
7. Explain the meaning of the following magnetic field and magnetic lines of force
8. Describe how you would shield a magnetic material from a magnetic field and state one application of magnetic shielding.
9. Describe the methods of demagnetizing a permanent magnet.
10. Use domain theory to explain the difference between magnetic and non-magnetic materials.
11. (a) What is meant by neutral point as applied to a magnetic field?

    (b) (i) Draw a diagram to show the magnetic field pattern due to an iron ring placed in the earth's magnetic field.

    (ii) State one application of the effect illustrated in b (i).

    (c) Name two properties of a magnet.

    (i) What are ferromagnetic materials? Give two examples of such materials.

    (ii) (a) State the basic law of magnetism.

    (b) Explain how you would identify the polarities of a magnet whose poles are not marked?

    (iii)Using domain theory explain the process of magnetization.