ELECTROSTATICS.

This is the study of charges at rest.

AN ELECTRIC CHARGE.

Is the deficiency or surplus of electrons in a material or atom.
Therefore, electric charges are either positive or negative.

ORIGIN OF CHARGE.

Matter is made up of atoms and an atom consists of three particles, namely; protons, neutrons and electrons.

The protons are positively charged and are located in the nucleus of an atom, the neutrons are neutral (have no charge) and are also located in the nucleus of an atom, while the electrons are negatively charged and move around the nucleus. Therefore, the nucleus has a net positive charge due to the charge on the protons.

For a neutral atom (an atom which is not charged or which has no charge), the total number of protons in the nucleus is equal to the total number of electrons around the nucleus.

When an atom or material loses some of its electrons, it becomes positively charged and when it gains electrons, it becomes negatively charged. This is the origin of charge.

NOTE: The charge is neither created nor destroyed during charging but can be transferred from one body to another. This is **the principle of conservation of charge**.

A negatively or positively charged atom is called an **ion.**

TYPES OF CHARGE.

There are two types of charges;
1. Positive charge.
2. Negative charge.

POSITIVE CHARGE.

This is the charge acquired by an atom or material by loss of electrons.

NEGATIVE CHARGE.

This is the charge acquired by a material or an atom by gain of electrons.

Examples;
1. When a glass rod is rubbed with silk or fur, the glass rod becomes positively charged and the silk material becomes negatively charged.
   This is because the glass rod loses electrons and the silk gains the electrons.
2. When an ebonite rod is rubbed with fur, the ebonite rod becomes negatively charged whereas fur becomes positively charged. This is because the ebonite rod gains electrons and the fur loses electrons.

MATERIAL BECOMES POSITIVELY CHARGED.	MATERIAL BECOMES NEGATIVELY CHARGED.
Glass rod	Silk or fur
Fur	Ebonite rod
Paper	Plastic rulers
Fur and wool	Polythene rod.

THE LAW OF CHARGES (THE LAW OF ELECTRO-STATICS)

This law states that like charges repel while unlike charges attract.

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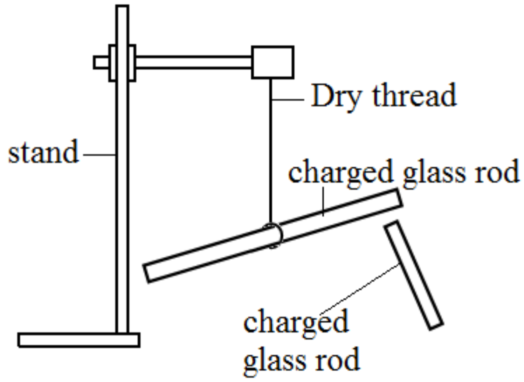
AN EXPERIMENT TO VERIFY THE LAW OF ELECTROSTATIC:



A dry glass rod is rubbed with a silk cloth so as to gain a positive charge. It is then suspended by a dry thread from a retort stand.
Another dry glass rod is also rubbed with a silk cloth and then brought near the suspended rod.
It is observed that the two charged glass rods repel each other.
A polythene rod is also rubbed with fur so as to acquire a negative charge and then brought closer to the suspended glass rod.
It is observed that the two charged rods attract each other. Therefore, like charges repel while unlike charges attract.

CONDUCTORS AND INSULATORS.

A conductor is a material with free or mobile electrons that allow heat and electricity to flow through it easily.
Examples of conductors;
- All metals.
- Graphite.
- Mercury.

An insulator is a substance with strongly bound electrons that it does not conduct heat and electricity easily.
Examples of insulators;
- Glass
- Polythene
- Ebonite
- Cellulose
- Acetate
- Perspex.
- Wool.
- Silk.

DIFFERENCE BETWEEN CONDUCTORS AND INSULATORS.

Conductors	**Insulators**
They have free and mobile electrons.	They have firmly bound electrons.
They acquire mobile charges.	The charges acquired are fixed.

ELECTRIFICATION OR CHARGING OF A BODY.

There are three methods of charging a body.
i. **Friction (rubbing)**. This is suitable for charging insulators.
ii. **Induction method**. This is suitable for charging conductors.
iii. **Contact method (conduction method)**. This is suitable for conductors.

Note: Conductors can also be charged using an electrophorus.

How bodies acquire charges when rubbed with each other.

When an insulator is rubbed with another insulator of another material, heat is generated.
The insulator with a lower work function loses electrons and the other insulator with a higher work function gains those electrons.

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The one that loses electrons becomes positively charged and the other that gains electrons become negatively charged.

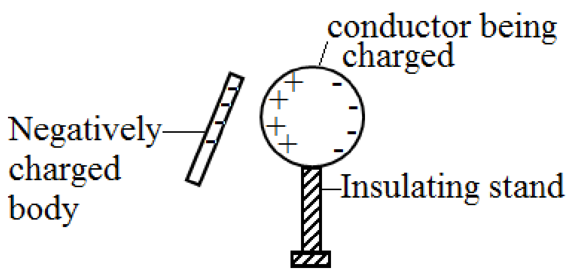
Question: Explain why brass or a metal cannot be charged by rubbing
Answer: Brass is a good conductor. When it is charged by rubbing, the charges are conducted to the earth through the body/skin.

NOTE: Work function is the minimum amount of energy required to remove an electron from a material.

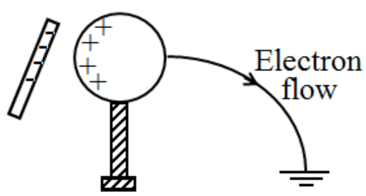
CHARGING BY INDUCTION (ELECTROSTATIC INDUCTION)
This is the process of charging a conductor by bringing a charged body close to it but without touching it.
In this method, the body being charged acquires a charge opposite to that of the charging body.
This method is mainly used to charge conductors.
The conductor being charged should be placed on an insulating stand to avoid charge leakage.

NOTE: Charge leakage is the flow or loss of charge to the earth.

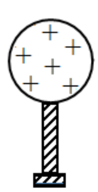
AN EXPERIMENT TO CHARGE A BODY POSITIVELY BY INDUCTION



- The body to be charged is placed on an insulating stand.
- A negatively charged body is brought near the body to be charged.
- The free electrons (negative charges) of the body or conductor are repelled to the remote side (far side) of the conductor and positive charges are induced on the near side.
- With the negatively charged body still in place, the conductor is earthed by touching it such that electrons flow to the earth.



- The earthing is removed and then the charging body is also removed.
- The conductor remains positively charged.



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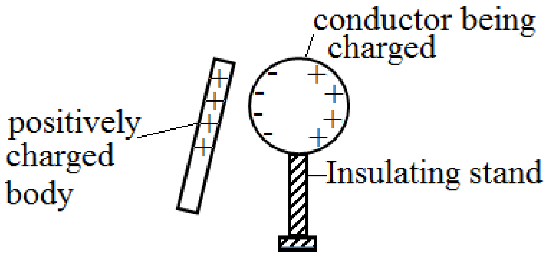
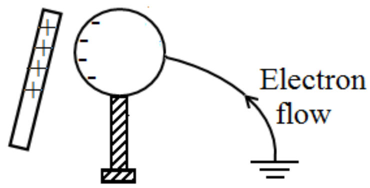
AN EXPERIMENT TO CHARGE A BODY NEGATIVELY BY INDUCTION

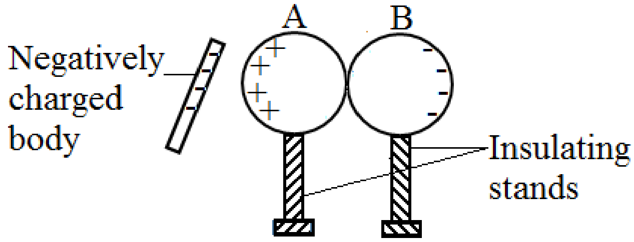


- The conductor to be charged is placed on an insulating stand.
- A positively charged body is brought near but not touching the conductor.
- The free electrons of the conductor are attracted by a positive charge of the charging body to the near side and positive charges are induced on the far side.
- With the charging body still present, the conductor is earthed by touching it such that electrons flow from the earth to neutralize the positive charge.



- The earthing is removed and then the charging body is also removed.
- The negative charge distributes itself and the conductor remains negatively charged.

AN EXPERIMENT TO CHARGE TWO CONDUCTORS (BODIES) WITH DIFFERENT (OPPOSITE) CHARGES SIMULTANEOUSLY BY INDUCTION



- The test conductors A and B are placed on insulating stands and in contact.
- A negatively charged body is brought near conductor A.
- Positive charges are induced on the side of A near the charging body and negative charges are induced on the furthest side of B.
- The conductors A and B are then separated when the charging body is still in place.
- The charging body is then taken away.
- The charges on the conductors A and B are tested. They are found to have opposite charges.

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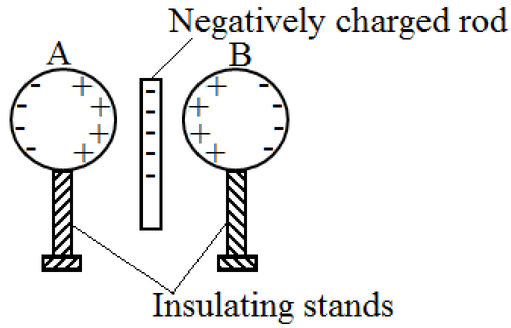
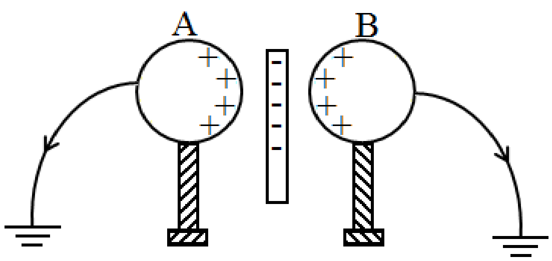
AN EXPERIMENT TO CHARGE TWO CONDUCTORS WITH THE SAME CHARGE SIMULTANEOUSLY BY INDUCTION

(a) Describe an experiment to charge two conductors positively by induction simultaneously.

Answer:



- The test conductors A and B are placed on insulating stands as shown above.
- A negatively charged rod is placed in between the conductors.
- While the rod is still in place, A and B are earthed by touching them such that electrons flow to the earth as shown below.



- The earthing is removed and the rod is then taken away.
- The bodies A and B are tested for charge and are each found with a positive charge.

NOTE: To charge a conductor by induction method;
-The conductor must be placed on an insulator to avoid charge leakage.
-The charge on the charging body must be of opposite sign to the charge required.

(b) Describe an experiment to charge two conductors negatively by induction simultaneously (Assignment)

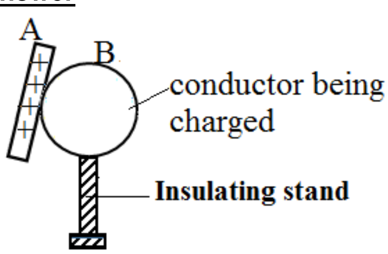
CHARGING BY CONTACT METHOD (CONDUCTION METHOD)

This is the process by which both the charged and un-charged bodies are made to touch each other and the uncharged body acquires a similar charge to that of the charged body.
The charge on the charging body reduces in magnitude.

Question

Describe an experiment to charge a body positively by contact method

Answer



The conductor B to be charged is supported on an insulating stand.
A positively charged rod A is brought into contact with conductor B
The free electrons of B flow towards A and neutralize the charge on it.
The rod A is then taken away.

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Conductor B remains with a positive charge and the rod A remains with a reduced positive charge.

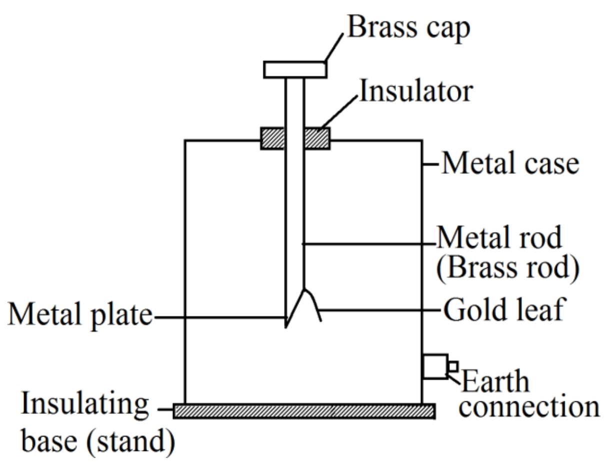
Question
Describe an experiment to charge a body negatively by contact method.

DIFFERENCES BETWEEN INDUCTION METHOD AND CONTACT METHOD OF CHARGING A BODY:

INDUCTION METHOD	CONTACT METHOD
The charging body and the uncharged body do not touch each other.	The charging and the uncharged body touch each other.
The body being charged acquires an opposite charge to that of the charged body.	The body being charged acquires a similar charge to that of the charging body.
The magnitude of charge on the charging body remains constant.	The magnitude of charge on the charging body reduces.

THE GOLD LEAF ELECTROSCOPE (GLE)

STRUCTURE



It consists of a brass cap and a brass plate joined by a brass rod. A gold leaf is connected to the lower end of the brass rod and is free to deflect (diverge or to collapse)
The metal case prevents disturbance from wind or air currents.

ACTION OF THE G.L.E (HOW IT WORKS)
When a charged body is brought near the cap of the electroscope, an opposite charge is induced on the cap of the electroscope while a charge similar to that of the body is induced on the plate and the leaf.
The like charges on the leaf and the plate repel each other and the leaf diverges

USES OF THE GOLD LEAF ELECTROSCOPE
The gold leaf electroscope is a device used for;
- Detecting the presence of electric charge on a body i.e., determine whether a body is charged or not
- Determining the nature of charge (whether positive or negative)
- Determining whether a body is a conductor or an insulator

CHARGING A GOLD LEAF ELECTROSCOPE
There are 2 methods of charging a gold leaf electroscope
-Contact method
-Induction method

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CHARGING A G.L.E BY CONTACT METHOD

- A charged rod is rubbed on the cap of the gold leaf electroscope for some time
- The leaf diverges (rises). When the rod is taken away, the leaf remains diverged showing that it is charged.
- When the gold leaf electroscope is tested for charge, it is found to have a similar charge to that which was on the charged rod.

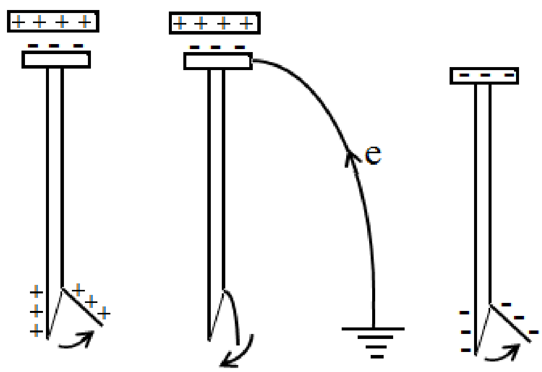
NOTE: If the leaf falls after removing the charged rod, it means that the electroscope is not yet charged and so the process is repeated.

Question: Describe how you can charge a gold leaf electroscope negatively by contact method (conduction method)
Answer:

- A negatively charged rod is brought into contact with the cap of the electroscope to be charged. The free electrons (negative charges) are repelled to the plate and the leaf. The leaf then diverges.
- The rod is then taken away.
- The negative charges on the leaf and the plate distribute themselves and the electroscope remains negatively charged.

CHARGING AN ELECTROSCOPE NEGATIVELY BY INDUCTION METHOD

- A positively charge rod is brought close but not touching the metal cap of the electroscope.
- The free electrons from the cap, plate and leaf are attracted to the cap near the rod.
- The leaf and the plate remain with positive charges and they repel each other hence the leaf diverges.
- While the charged rod is still in place, the cap is earthed by touching it. Electrons then flow from the earth and neutralize the positive charge on the leaf and the plate. The leaf then falls/collapses.
- The earthing is removed and then the rod is taken away
- The negative charge on the cap distributes itself on the metal rod and gold leaf. The leaf thus diverges again.
- Therefore, the gold leaf electroscope has acquired a negative charge.



Question
Describe how you can charge a gold leaf electroscope positively by induction (assignment).

AN EXPERIMENT TO DETECT THE PRESENCE OF CHARGE ON A BODY
The body to be tested is brought close but not touching the cap of a neutral gold leaf electroscope.
If the leaf diverges, then the body is charged. If no divergence occurs, then the body is not charged.

AN EXPERIMENT TO DETERMINE THE NATURE (SIGN) OF CHARGE ON A BODY

- The gold leaf electroscope is first charged with a known charge.
- The body of unknown charge is brought near the cap of the electroscope.
- If there is increase in divergence of the leaf, then the body has the same charge as that of the electroscope.
- If there is a decrease in divergence, then either the body has an opposite sign of the charge to that on the electroscope or the body is a neutral conductor

Note: From the above observations, ***increase in divergence of the leaf is the surest way of testing for sign of charge on a body***.

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AN EXPERIMENT TO DETERMINE WHETHER A BODY IS A CONDUCTOR OR AN INSULATOR

- The GLE is charged either positively or negatively and the divergence of the leaf is noted.
- The body to be tested is brought near the cap of the electroscope.
- If there is no change in divergence of the gold leaf, then the body is an insulator. If the divergence reduces then the material is a conductor.

AN EXPERIMENT TO COMPARE THE MAGNITUDE OF CHARGE ON CHARRGED BODIES

- Two charged bodies are brought near the cap of a neutral gold leaf electroscope one at a time. The divergences of the leaf are noted and compared.
- The body that causes greater divergence carries more charge than the one which causes least divergence.

PRECAUTIONS CONSIDERED WHEN CARRYING OUT EXPERIMENTS IN ELECTROSTATICS

i) The experiment should be carried out in dry conditions. This is because under moist conditions, there will be charge leakage to the earth since water/moisture is a conductor.
ii) The cap of the gold leaf electroscope shouldn't be touched unless there is need to earth it.
iii) The metal casing of the gold leaf electroscope must be earthed to avoid any charge from the external fields that might interfere.

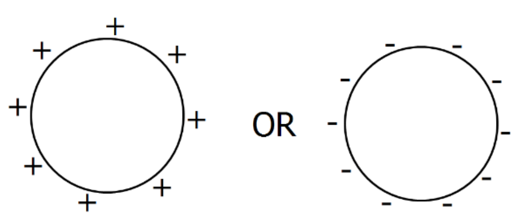
CHARGE DISTRIBUTION ON A CONDUCTOR (SURFACE CHARGE DENSITY)

Charge Density is the quantity of charge per square metre of a charged conductor.
Charge distribution on a conductor is determined by the shape of the conductor.

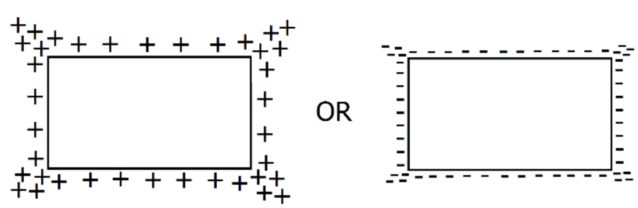
On a given conductor, the charge is concentrated at the sharp points of the conductor. This is because there is a small surface area at the sharp points.

DISTRIBUTION OF CHARGE ON DIFFERENT SHAPES OF THE CONDUCTORS

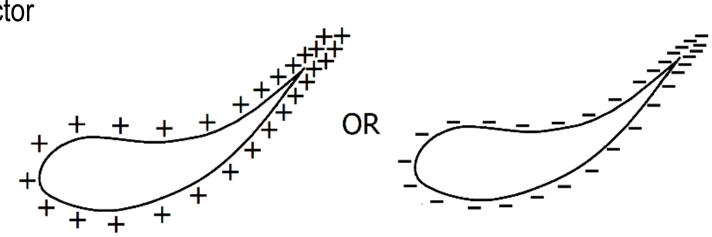
i. Spherical conductors: The charge distribution of spherical conductors is uniform.



ii. Rectangular conductor



iii. A pear-shaped conductor



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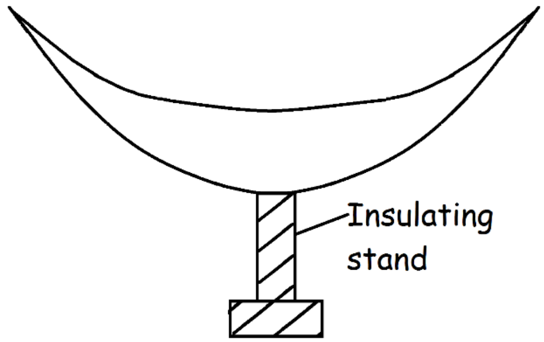
Exercise
The diagram below shows a negatively charged conductor placed on an insulating stand.



i. Explain why the conductor is placed on an insulating stand.
ii. Redraw the diagram and show the distribution of charge on the conductor.

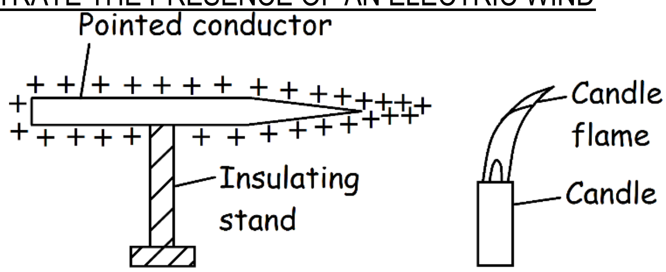
POINT ACTION (ACTION AT A POINT OR CORONA DISCHARGE)
This is the apparent loss of charge at the sharp points of a charged conductor due to a high charge density at these points.

Due to the high charge density at sharp points of a charged conductor, ionization of air around the sharp point occurs. Ions of like charges in air are repelled away and ions of unlike charges are attracted to the sharp point and **neutralization occurs**.

Question: Explain the term action at points/ corona discharge.
Answer
At sharp points of a charged conductor, there is a high concentration of charge which ionizes the air around. Ions of opposite charge to that at the sharp points are attracted and neutralize the charge on the sharp points while ions of similar charge are repelled.

The repelled ions form an electric wind.

AN EXPERIMENT TO DEMONSTRATE THE PRESENCE OF AN ELECTRIC WIND



A sharp pointed conductor (wire) is placed on an insulating stand and then given a charge, either positive or negative.
The candle flame is placed at a short distance away from the pointed end of the charged conductor.
The candle flame is seen to be blown away from the conductor and may even blow out.

This shows the presence of an electric wind.

APPLICATIONS OF ACTION AT POINTS
- In the lightning conductors (arrestors)
- In the Van- de Graaf generators
- In the discharging of air crafts in flight. The air crafts are fitted with sharp points at the back of the wings to discharge them during flight.
- It can be used to charge a gold leaf electroscope

LIGHTNING AND LIGHTNING CONDUCTORS

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Lightning is a discharge which occurs at the clouds when the charges from the clouds are accelerated to the earth. It is always accompanied by an intense flash of light.

Qn 1. Explain the dangers of lightning. (UNEB 2018)

The flow of large current (charge) occurs between (from) a charged cloud and (to) the earth. This causes fire, electrocution (shock), death (of cows, people), damage of buildings and electronic appliances, etc.

Qn 2. Explain how lightning can destroy a building or an object.

When a charged cloud passes over a building or an object on the earth, an opposite charge is induced on the top of the building and a similar charge is repelled to the ground through the building/ object.
The flow of charges through the building result into the production of heat that can burn down the building.

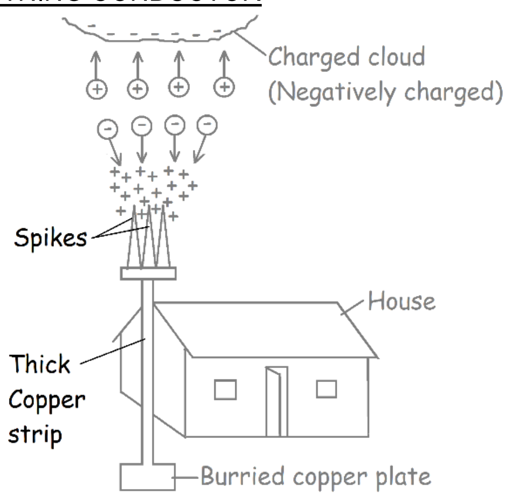
THUNDER

Thunder is a sound produced by the rapid expansion and contraction of air between the clouds and the earth due to the heat produced in the atmosphere during lightning.
The heat produced results from collisions between charges and air molecules in the atmosphere.
This heat causes air to expand and due to the low temperatures in the upper atmosphere, the air again contracts suddenly.

THE LIGHTNING CONDUCTOR

This is a device that prevents structures from being damaged by lightning by safely passing charges to the ground.
It consists of sharp spikes on top of a copper strip. The copper strip passes over the wall of a building and runs down to a buried copper plate or brass plate in the ground.

STRUCTURE AND ACTION OF A LIGHTNING CONDUCTOR



When the charged cloud passes over a lightning conductor, it induces an opposite charge on the spikes of the conductor.
The high electric field intensity on the spikes ionizes air around them.
Ions of charges similar to those on the spikes are repelled to the cloud and neutralize the charges on the cloud, while those opposite are attracted and discharged at the spikes. The electrons formed flow to the earth through the conductor.
In this way, the charge from the cloud is safely conducted to the ground

Question

Explain why it is not safe to touch a lightning conductor when it is raining.

Answer

If the conduction is touched, the charge flowing to the earth through it can be conducted through the body causing a severe shock which can damage a person or kill her/him.

PRECAUTIONS TAKEN AGAINST BEING STRUCK BY LIGHTING

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i) Find shelter in a fully enclosed building or a fully enclosed hard topped car during a storm or rain. Avoid sheds, tents and covered porches during rain. Turn off the air conditioner of the car.
ii) Avoid standing under isolated tall trees, poles or metal objects when it rains because these are easy targets for lightning. It is better to go to a low-lying open area away from trees so long as the area is not subjected to flooding.
iii) Avoid using telephones or any electrical appliances during rain.
iv) Stop swimming or taking a bath or avoid any running water during heavy rain even when you are in a house because water is a conductor.
v) Avoid carrying an umbrella. It is better to get soaked than to die
vi) Find a ditch to lie in incase you are caught in an open area during rain or storm.
vii) Make yourself the smallest target possible in any open area during a storm/rain. This is done by squatting low to the ground with your hands on your knees and your head between the knees. Do not lie flat to the ground because this makes you a larger target for lightning.

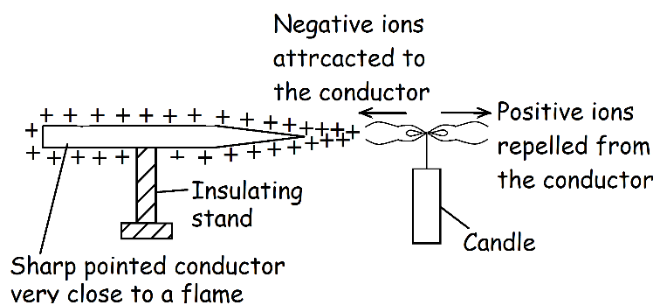
Note:
Lightning can damage computers, TVs, telephones, electronics and other systems when connected to power sources hence it's advisable to un plug them during a storm/rain.

DISTRIBUTION OF CHARE ON A CHARGED HOLLOW CONDUCTOR, IN A FLAME AND IN THE ATMOSPHERE

a) A CHARGED HOLLOW CONDUCTOR
For a charged hollow conductor, charge resides only on the outside and no charge resides inside.
This was showed by Faraday in his experiment called the Faraday's Ice Pail Experiment.
b) A FLAME
A flame contains both negative and positive ions.
c) THE ATMOSPHERE
The atmosphere also contains both negative and positive ions.

AN EXPERIMENT TO DEMONSTATE THE PRESENCE OF BOTH POSITIVE AND NEGATIVE IONS IN A FLAME

- A sharp pointed conductor (or wire) is placed on an insulating stand and then given a positive charge.
- The pointed end of the charged conductor is placed very close to a candle flame.
- The candle flame is seen to be drawn out both towards the pointed end and away from the pointed end at the same time.
- This is because negative ions in the flame are attracted towards the positive charge while positive ions in the flame are repelled away from it.



Note:
The difference between this experiment and that of the electric wind is that in this experiment the conductor is placed very close to the flame while in the electric wind experiment, the conductor is at some short distance from the flame.

Question 1:
a) Explain the distribution of charge in;
   i) A flame
   ii) The atmosphere
b) Explain why when a charged rod is passed through air above a flame it loses its charges.

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Solution

a) (i) In a flame, the gas molecules are vibrating very rapidly. Frequent collisions between the molecules occur.
This makes electrons to be knocked out from some of the molecules.
The molecules which lose electrons become positively charged.
At the same time, some of the free electrons attach themselves to neutral molecules which become negative ions.
Hence a flame contains both positive and negative ions.

(ii) The atmosphere contains both positive and negative ions. These ions are produced by the passage of radiations through the gases in the atmosphere which ionize the gases.
These radiations include cosmic radiations, the ultra violet radiations from the sun and radiations from radioactive elements.

b) When a charged rod is passed through air above a flame such as a Bunsen flame, ions of opposite charge in the flame are attracted to the rod and the charge on the rod becomes neutralized hence the rod loses the charge.
This is because a flame contains both a positive and negative ion

Question 2:

Explain why a charged conductor will slowly lose its charge over a period of time even when mounted to an insulator.

Solution

The atmosphere contains both positive and negative ions due to ionization of air by radiations.
Ions of opposite sign are slowly attracted towards the conductor and the charge on it is slowly neutralized.
Therefore, the conductor will slowly lose its charge.

ELECTRIC FIELDS

An electric field is a region around an electric charge where an electric force is experienced.

ELECTRIC FIELD LINES

An electric field line is a path or direction in an electric field along which a free positive charge placed in that field would tend to move.
Or it is a line drawn in an electric field such that its direction at any point gives the direction of the electric field at the point

PROPERTIES/ CHARACTERISTICS OF ELECTRIC FIELD LINES

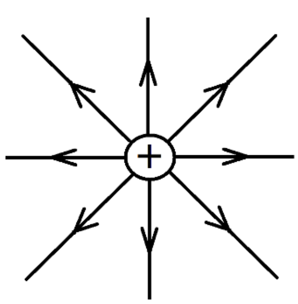
i) They begin and end on equal and opposite quantities of electric charge
ii) They are in a state of tension
iii) They repel one another side ways
iv) They never cross each other
v) They begin from a positive charge and end on an equal negative charge.

NEUTRAL POINT

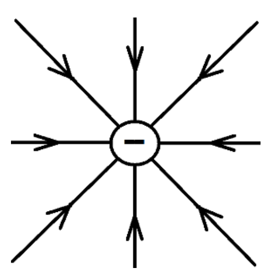
A neutral point is a point in an electric field where the resultant electric force is zero.

ELECTRIC FIELD PATTERNS

a) An isolated positive charge.



b) An isolated negative charge.



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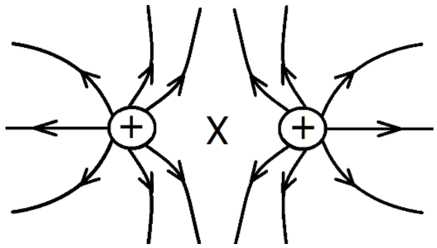
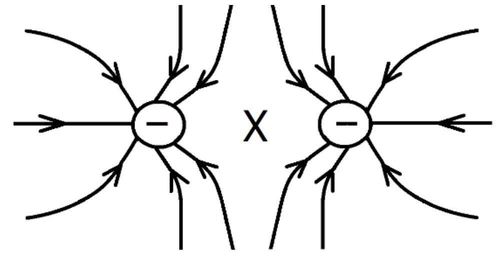
c) Like (similar) charges near each other.

i) Two positive charges near each other.



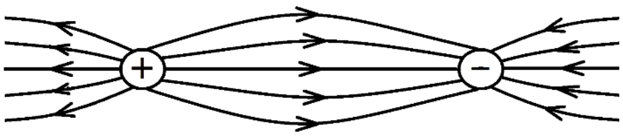
X is the neutral point.

ii) Two negative point charges near each other.

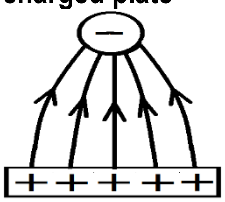


X is a neutral point.

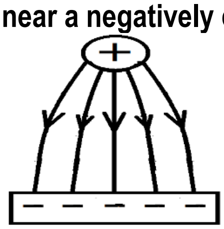
d) Unlike (opposite) charges near each other.



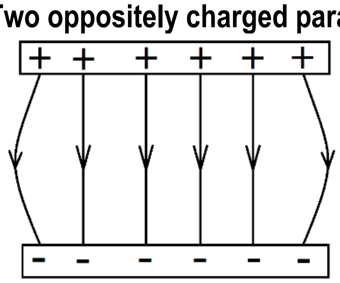
e) A point negative charge near a positively charged plate



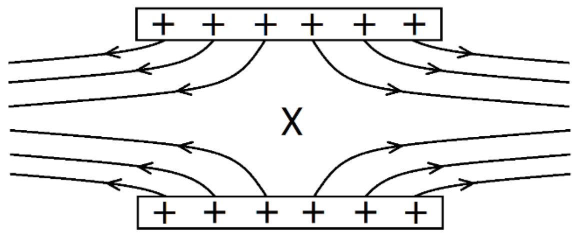
f) A point positive charge near the earth (or near a negatively charged plate)



g) Two oppositely charged parallel plates.

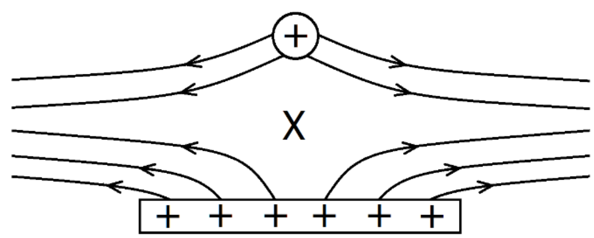


h) Two similarly charged parallel plates.



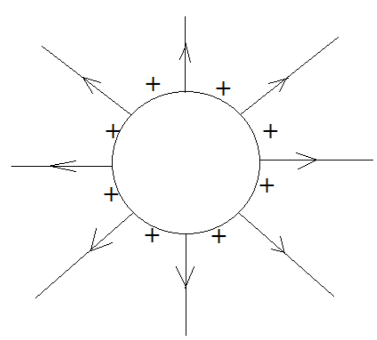
X is a neutral point.

i) A point positive charge near a positively charged plate.



X is a neutral point.

j) **A positively charged hollow conducting sphere**



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APPLICATIONS OF ELECTROSTATICS

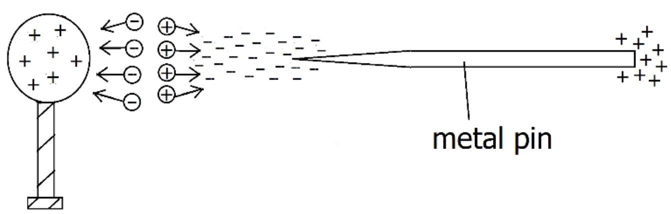
i) It is applied in photocopying machines and printers through a process called xerography to copy images
ii) It is used in the generation of electricity using the van der Graaf generator
iii) It is used in a lightning conductor to protect buildings from being damaged by lightning.
iv) It is used in electrostatic painting.
v) It is used in the removal of particles of ash, soot or dust from factory chimneys and power stations.

Explanations

- In electrostatic painting, the particles of paint are given a positive charge as they leave the nozzle of the spray gun. The object to be painted is earthed so that there is an electric field between the nozzle and the object.
  The charged paint particles follow the field lines and are deposited evenly all over the surface of the object such as a car body or bicycle frame.
- In the cleaning of factory chimneys and power stations, the gas containing the particles of the ash or soot is passed between positively charged metal plates and negatively charged wires.
  The strong electric field around the wire ionizes the gas and creates negative ions and positive ions. The negative ions flow towards the positive plates and as they flow, they charge the particles of dust or ash negatively. The particles of dust or ash are then attracted by the metal plate and collect on them.
  The metal plates are then shaken periodically to collect the soot, ash or dust down in bins or troughs.

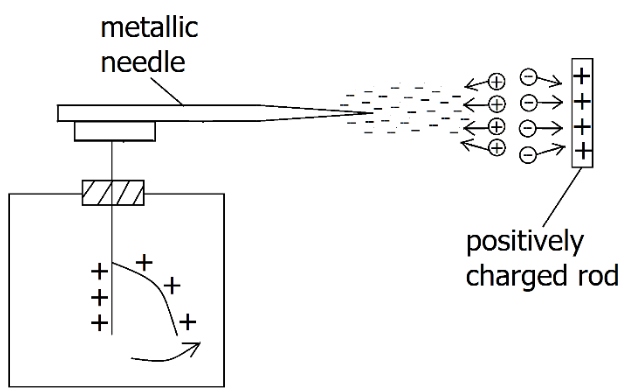
REVISION QUESTIONS ON POINT ACTION:

1) Explain what happens when a positively charged conductor is placed near a metal pin pointing towards it.
   Solution



When the pin is brought near the conductor, the conductor induces negative charge on the sharp point of the pin and a positive charge on the far end.
Negative charge concentrates on the sharp point resulting into a high charge density. This ionizes air around the sharp point forming both positive and negative ions.
The negative ions are repelled by the negative charge on the tip of the pin towards the conductor and the conductor loses charge by neutralization.

2) Describe an experiment to charge a gold leaf electroscope positively by point action.
   Solution



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A metallic needle is placed on the cap of a gold leaf electroscope.
A positively charged rod is brought near the sharp point of the needle.
The gold leaf is observed to diverge rapidly.
The rod is then taken away.
The leaf remains diverged.
The electroscope is tested for charge and it is found to be positively charged.

Explanation

When the positively charged rod is brought near the pointed end of the needle, it induces a negative charge at the sharp end of the needle and a positive charge at the plate and the leaf. So the leaf diverges due to repulsion.
The high concentration of negative charge at the sharp end ionizes air around it forming positive and negative ions.
The positive ions are attracted to the sharp end and neutralization occurs. The electroscope thus remains with a positive charge.
At the same time, the negative ions are repelled towards the charged rod and also neutralization occurs there. Hence the rod loses its charge.

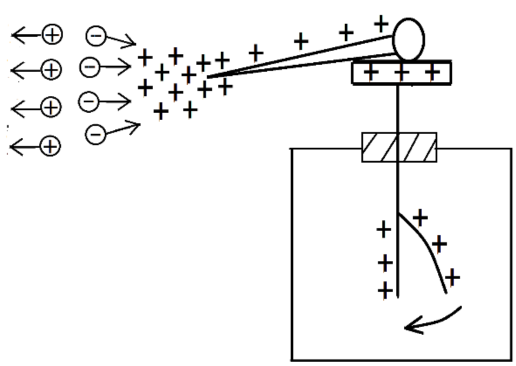
NOTE A sharp point can enable a conductor to gain (collect) charge or to lose charge. In the experiment above (in question 2), the sharp point of the needle acts as a collector of charge.

3) a) State the two main effects of point action (action at sharp points)
b) Describe an experiment to show the discharge (loss of charge) of a positively charged gold leaf electroscope through a sharp point.

Answers:

a) -Loss of charge by a conductor
-Collection of charge (gain charge) by a conductor

b) AN EXPERIMENT TO SHOW DISCHARGE OF A POSITIVELY CHARGED ELECTROSCOPE THROUGH A SHARP POINT.



A pin is placed on the cap of the positively charged gold leaf electroscope.
The pin acquires a positive charge by contact but with a high charge density at a sharp point.
Point action takes place at the sharp point where air is ionized forming both positive and negative ions.
Positive ions are repelled away by the charge on the sharp point while the negative ions are attracted towards the point and they neutralize some of the positive charge on the gold leaf electroscope.
The divergence of the leaf reduces.
Eventually the electroscope loses its charge.

QUESTION

Describe an experiment to show a sharp point as a collector of charge.

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MAGNETISM

Magnetism is the property of a magnet to attract other materials called magnetic materials.
A magnet is a material which attracts magnetic materials.

MAGNETIC MATERIALS AND NON-MAGNETIC MATERIALS

A magnetic material is a material that can be attracted by a magnet.

Examples of magnetic materials

- Iron
- Steel
- Nickel
- Cobalt

NOTE: All magnetic materials are Ferromagnetic materials.

A non-magnetic material is a material that cannot be attracted by a magnet.

Examples of non-magnetic materials

- Copper
- Brass
- Glass
- Rubber
- Wood
- Plastics, etc.

USES OF MAGNETS

- They are used in bicycle dynamos.
- They are used in electric motors.
- They are used in loud speakers.
- They are used in telephones.
- They are used in generators.
- They are used to separate smaller magnetic materials from floor or powder.
- They are used to lift heavy metals such as iron scrap ,a steel from one place to another in industries.

CLASSIFICATION OF MATERIALS IN MAGNETISM

1. Ferromagnetic materials

   These are materials that get strongly magnetized in the direction of the magnetizing field.

   OR

   These are materials which are strongly attracted by a magnet. E.g., Iron, Steel, Cobalt and Gadolinium.

   - All magnetic materials are ferromagnetic materials.
   - Their magnetic domains (group of dipoles) line up easily and readily in the same direction.

2. Paramagnetic materials

   These are materials that get weakly or slightly magnetized in the direction of a strong magnetizing field.

   OR

   These are materials that are weakly attracted by a magnet. E.g., Copper, Aluminium, Uranium, Platinum. Since their attractive force is very small, paramagnetic materials are considered to be non-magnetic materials.

3. Diamagnetic materials:

   These are materials that are weakly repelled by strong magnet. E.g. bismuth, benzene.

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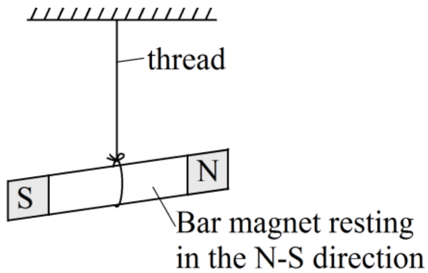
POLARITY OF A MAGNET (POLES OF A MAGNET)
Every magnet has two poles i.e., the North Pole (N) and the South Pole (S).
A magnetic pole is defined as the point on a magnet where the resultant attractive force is concentrated/highest.
The North Pole (N): Is the pole of the magnet that is attracted to the geographic north.
The South Pole (S): Is the pole of a magnet which is attracted to the geographic south.

NOTE: The force of attraction or repulsion of a magnet is highest at the poles.

SUSPENDING A BAR MAGNET
When a bar magnet is freely suspended using a thread, it swings to and fro for a short time and then settles in the North-South direction.



THE LAW OF MAGNETISM
It states that like poles repel and unlike poles attract.

PROPERTIES OF A MAGNET
i) The attractive force of a magnet is highest at the poles.
This can be shown by dipping a magnet into iron filings. More iron filings are attracted at the poles than in the middle.
ii) When a magnet is freely suspended in air, it comes to rest while pointing in the North-South direction.
iii) Like poles repel and unlike poles attract.

HOW TO DETERMINE THE POLES (POLARITY) OF A MAGNET

Method I: BY SUSPENDING THE MAGNET
- A magnet whose poles are not known is suspended using a thread so that it can rotate freely.
- The magnet is given time to rest.
- The magnet rests in the North-South direction.
- The end pointing in the geographical North is the North Pole and the end pointing in the geographical South is the South Pole.

Method II: USING A MAGNET OF KNOWN POLES
- A magnet whose poles are to be determined is suspended using a thread so that it can rotate freely.
- A known pole of another magnet is brought closer to one pole of the suspended magnet.
- If there is attraction, then either the two close poles are unlike or the suspended material is just a magnetic material which has been attracted but not a magnet.
- If there is repulsion, then it is true that the two close poles are like poles.

Therefore, repulsion is the only sure test for polarity of a magnet.

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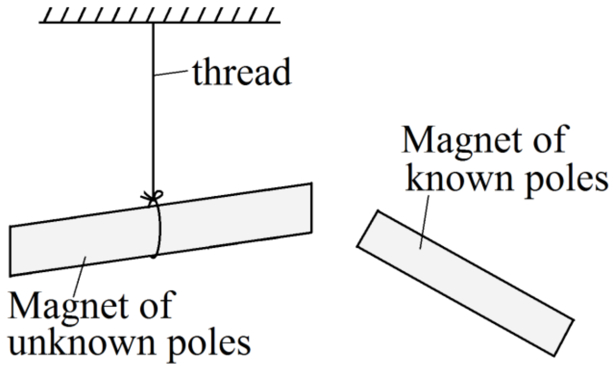


MAGNETIC FIELDS

A magnetic field is a region around a magnet where a magnetic force is experienced.
A magnetic field is made up of lines of force called magnetic field lines.
The direction of the magnetic field is given by the magnetic lines of force (magnetic field lines).
A magnetic field line (magnetic line of force) is defined as the line along which a magnetic force act.
Magnetic flux is a measure of the magnetic field strength over a given area. Magnetic flux is a vector quantity with both magnitude and direction.

Properties of the magnetic field lines

- They begin from the north pole and end on a south pole.
- They repel one another side ways.
- They never cross each other.
- They are in a state of tension and tend to shorten.

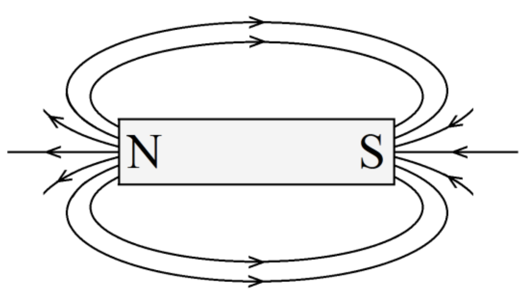
MAGNETIC FIELD LINE PATTERNS

There are two methods by which a magnetic field pattern of any magnet can be revealed, namely:

(i) The iron filing method.
(ii) The plotting compass method.

THE IRON FILINGS METHOD

The magnet whose field is to be revealed is placed on a flat table and a stiff piece of paper is placed on top.
Iron filings are then thinly and evenly sprinkled over the top of the paper.
The paper is gently tapped.
The iron filings arrange (align) themselves along the magnetic field lines. This reveals the pattern of the magnetic field.



NOTE: To keep this pattern permanent, a waxed paper is used which is quickly and evenly warmed to fix the iron filings using a Bunsen flame.

Advantages of the iron filings method

- It is quick because all the filings are arranged at once.

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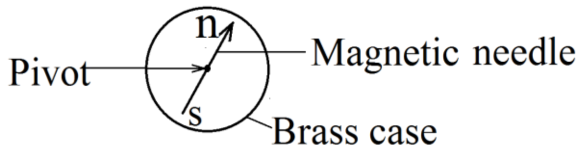
- It is cheaper than buying a plotting compass.

Disadvantages of the iron filings method

- It does not show the direction of the magnetic field lines.
- It is not a good method for weak magnets.

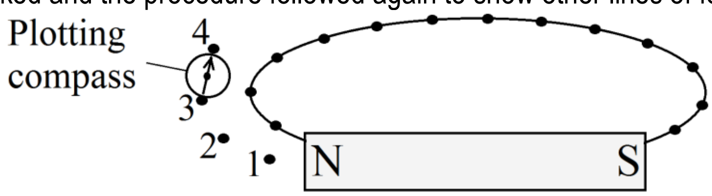
THE PLOTTING COMPASS METHOD

The diagram of a plotting compass



Procedure for the plotting compass method

The magnet whose field is to be revealed is placed on a white sheet of paper.
Using a pencil, a dot is marked 1 near the north pole of the magnet.
The plotting compass is then positioned on the paper such that the south pole (s) of the magnetic needle is over the dot 1. The next dot 2 is marked at the end of the north pole (n) of the needle.
The plotting compass is then moved to the next position so that south pole of the needle is over dot 2 and dot 3 is marked near the north pole.
The procedure is repeated up to the other end of the magnet and the dots are joined show the magnetic field line (line of force) whose direction is the direction of the magnetic needle.
Other starting dots are marked and the procedure followed again to show other lines of force.

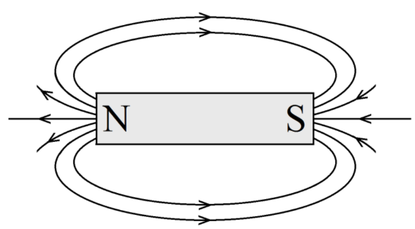


Advantages of the plotting compass method

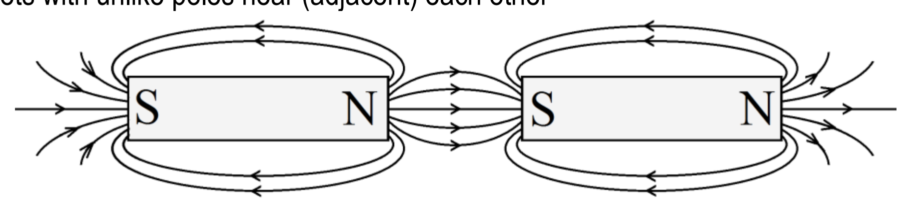
- It can reveal magnetic field pattern for even a weak magnet.
- It can show the direction of the magnetic field lines using the magnetic needle.

EXAMPLES OF MAGNETIC FIELD PATTERNS

i) An isolated magnet



ii) Two bar magnets with unlike poles near (adjacent) each other



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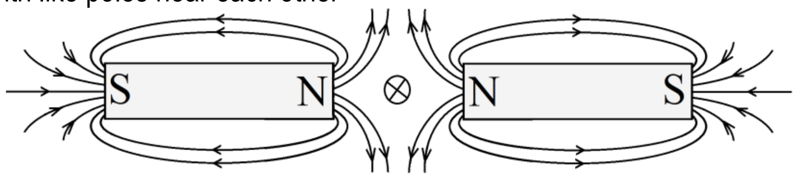
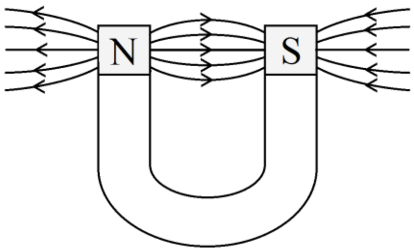
iii) Two bar magnets with like poles near each other



Where ⊗ is a neutral point

iv) A horse show magnet



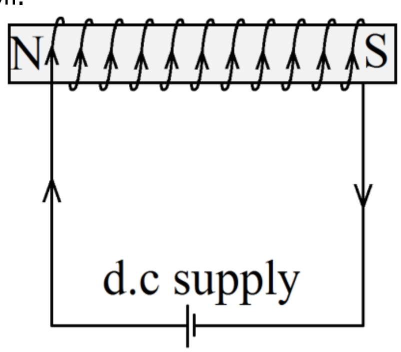
Definition of a neutral point
A neutral point is a point in a magnetic field where the resultant magnetic force is zero.

MAGNETISATION
This is the process of making a magnet from a magnetic material.

METHODS OF MAGNETISATION
- Electrical method using direct current (dc).
- Single touch method.
- Double touch or divided touch method.
- Hammering the magnetic material while pointing in the North-South direction but at an angle of 70^0 to the horizontal.

NOTE; Both the single touch and divided touch method are called the stroking methods.

ELECTRICAL METHOD
Procedure:
A *solenoid* is made by winding an insulated copper wire with 500 or more turns.
The solenoid is then connected in series with a battery (dc source) of about 6 volts or 12 volts.
A bar or rod to be magnetized is placed inside the solenoid.
The current is switched on and off.
The bar is removed from the solenoid and if it is a steel bar, it remains as a magnet, but if it is an iron bar, it lost its magnetism when current was switched off.



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NOTE:

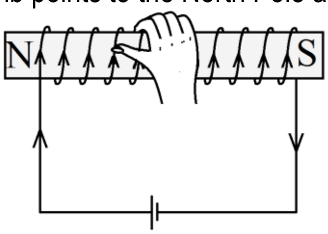
- A solenoid is a cylindrical coil of wire.
- It is not necessary to leave current to flow for a long time. This is because once the bar is magnetized, its magnetic strength cannot increase any farther and even the coil may be damaged through overheating.
- The polarity of the magnet produced depends on the direction of flow of current.

HOW TO DETERMINE THE POLES OF A MAGNET MADE BY THE ELECTRICAL METHOD

a) Using the direction of current:
We look at one end of the solenoid directly from that end. If the current is flowing in an anti-clockwise direction, then that end is the North Pole (as shown in figure (a) below). If the current is flowing in the clock-wise direction, then that end is the South Pole (as shown in figure (b) below).

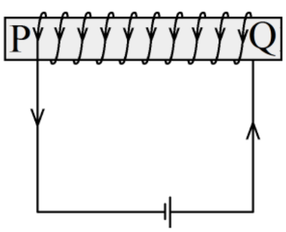
(a) (b)

b) Using the right-hand grip rule:
If the solenoid is gripped by the right hand such that the fingers point in the direction of the current, then the thumb points to the North Pole and the other pole is the South pole.

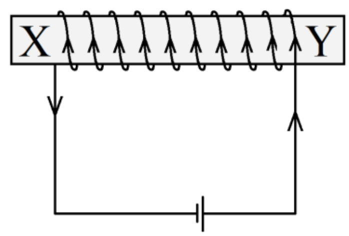


Question: Identify the polarities labelled P, Q, X and Y in the diagrams below.

a)



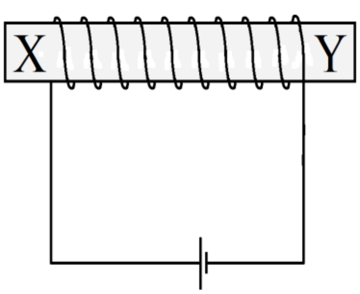
P is the…………………………pole;
Q is the…………………………pole



X is the………………………..pole; Y is the………………………..pole

b)

(c)



X is the………………………..pole; Y is the………………………..pole

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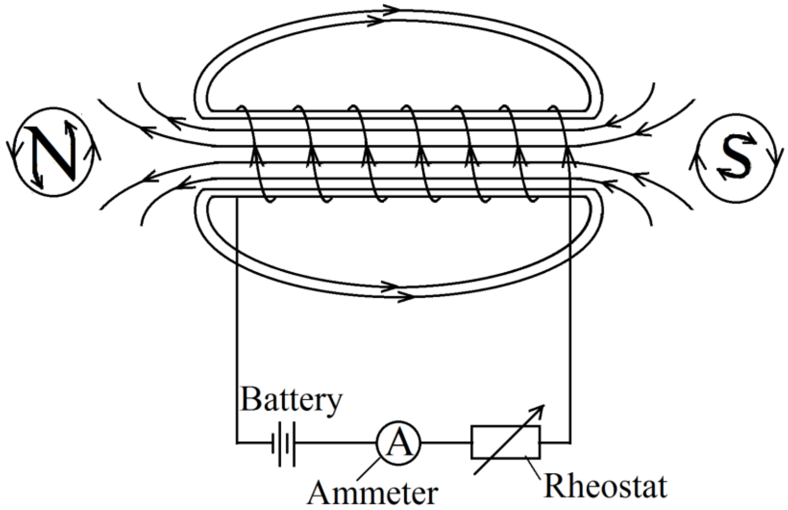
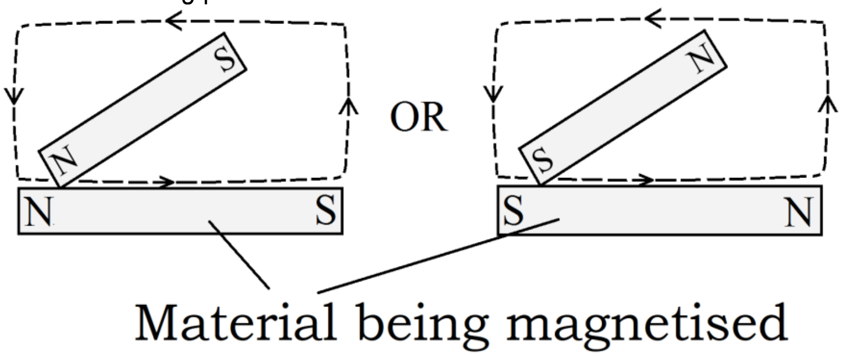
NOTE:
The Magnetic field pattern due to a solenoid carrying direct current is as drawn below.



SINGLE TOUCH METHOD
The magnetic material to be magnetized is placed on a table.
The material is stroked several times continuously from end to end in the same direction using one pole of a bar magnet. The material then becomes a magnet.
The pole of the magnetized material where stroking finishes is opposite to that of the stroking pole. The pole where stroking starts is similar to the stroking pole.



Precautions in the Single Stroking Method
(a) Between successive strokes, the stroking pole should be lifted high above the material being magnetized such that the magnetism already acquired by the material is not weakened.
(b) The stroking pole must stroke from the exact beginning of the material to the exact end.

Disadvantage of single touch method
The poles of the magnet produced may not be symmetrical i.e. one pole may be nearer one end than the other pole on the opposite end due to incomplete stroking.

DOUBLE TOUCH METHOD (DIVIDE TOUCH METHOD)
The material to be magnetized is placed on the table and then stroked from the center outwards towards the ends using two unlike poles of two magnets at the same time.
The material becomes a magnet and the pole produced at the end where stroking finishes is opposite to the stroking pole.

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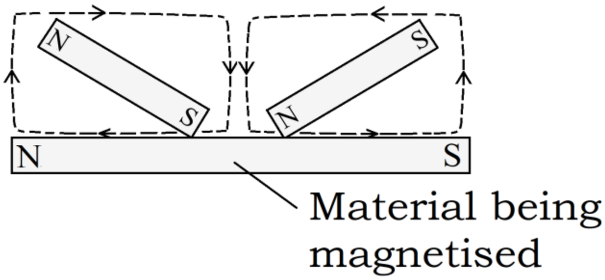
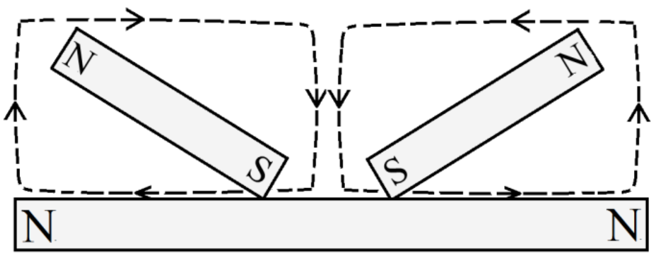


CONSEQUENT POLES

These are two like poles at both ends of a magnet.

They can be obtained when a material is stroked by double touch method using like poles of two magnets at the same time.



Such a magnet is not a normal magnet and does not settle in one direction when suspended.

DEMAGNETISATION

It is the process by which a magnet loses its magnetism.

METHODS OF DEMAGNETISATION

- Electrical method using alternating current (a.c).
- Heating the magnet.
- Dropping or hitting the magnet on a hard surface.
- Hammering the magnet while pointing in the East-West direction.

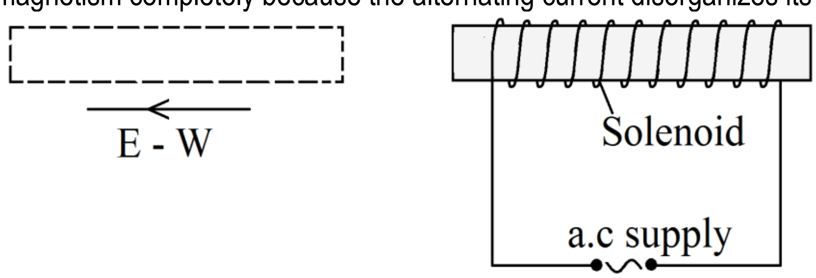
ELECTRICAL METHOD OF DEMAGNETIZATION

The solenoid through which an alternating current from an a.c supply is flowing is arranged such that its axis is in the East-West direction.

The magnet to be demagnetized is placed inside the solenoid.

With the alternating current still flowing, the magnet is slowly withdrawn from the solenoid to a long distance of several meters in the East-West direction.

The magnet loses its magnetism completely because the alternating current disorganizes its magnetism.



NOTE: This method demagnetizes a magnet completely.

HEATING THE MAGNET

The magnet is heated until it becomes red hot and then allowed to cool while lying in the East-West direction.

The magnet loses its magnetism.

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DROPPING THE MAGNET

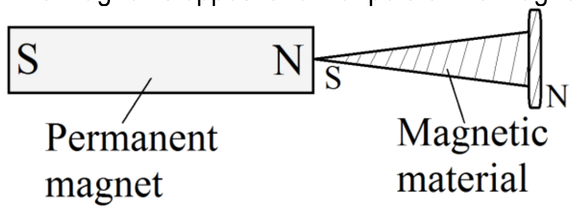
When a magnet is dropped on a hard surface for several times, it loses its magnetism.

HAMMERING THE MAGNET

When a magnet is hammered while in the East-West direction, it loses its magnetism.

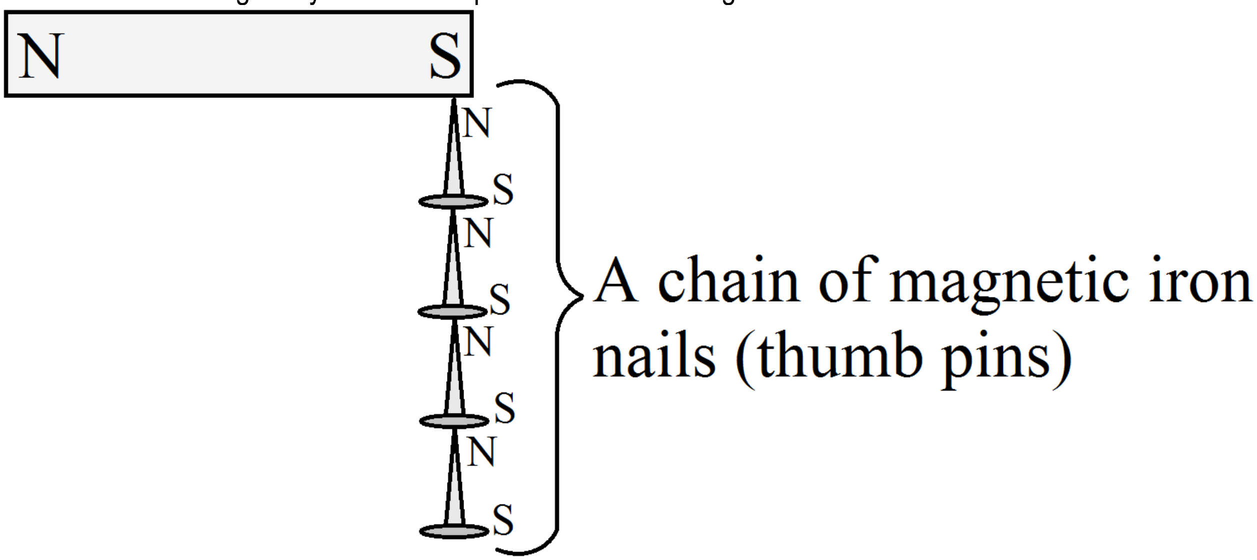
INDUCED MAGNETISM

Induced magnetism is the magnetism acquired by a magnetic material in contact with or near to a pole of a magnet.
The induced pole near the pole of the magnet is opposite to that pole of the magnet.



MAGNETIC CHAIN

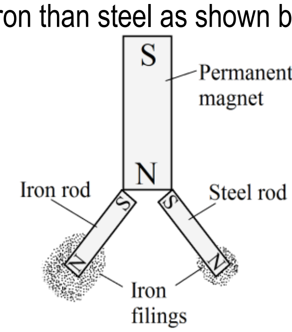
A magnetic chain can be formed as a result of induced magnetism.
This can be shown using many irons thumb pins which form a magnetic chain.



The permanent magnet induces magnetism in the first pin or nail which also induces in the second pin and the induction continues.

AN EXPERIMENT TO SHOW THE MAGNETIC PROPERTIES OF IRON AND STEEL

Two identical rods; one of iron and another of steel are each attached to the same pole of a permanent magnet and their free ends are dipped in iron filings.
The permanent magnet is then lifted high to raise the rods.
It is observed that more iron filings cling on iron than steel as shown below.



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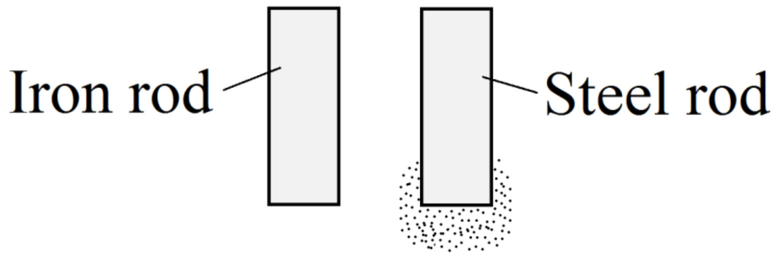
The permanent magnet is then detached from the rods while the rods are held in the hands. It is observed that all iron filings fall off from the iron and none falls off from the steel.



EXPLANATION

More iron filings cling on the iron rod than steel because it is easier to magnetize iron than steel. That is; iron acquires more magnetism than steel.

When the permanent magnet is removed, iron loses all its iron filings and steel loses none of its iron filings. This is because iron loses its magnetism but steel retains its magnetism for a long time.

Therefore, the magnetism acquired by iron is temporary and that acquired by steel is permanent.

SOFT AND HARD MAGNETIC MATERIALS

SOFT MAGNETIC MATERIALS

These are materials which are easy to magnetize and lose their magnetism easily. For example, soft iron.

USES OF SOFT MAGNETIC MATERIALS

- They are used in transformers.
- They are used in electromagnets e.g., in electric bells.
- They are used as keepers for proper storage of magnets.

Note: A magnet made from a soft magnetic material is a temporary magnet.

HARD MAGNETIC MATERIALS

These are materials which are hard to magnetize and retain their magnetism for a long time. E.g. steel.

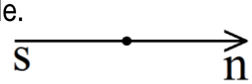
USES OF HARD MAGNETIC MATERIALS

They are used for making permanent magnets which are used in;

- Dynamos (generators).
- Electric motors.
- Loud speakers.
- Moving coil galvanometers.

THE DOMAIN THEORY OF MAGNETISM

This theory states that every magnet is made up of many tiny atomic (molecular) magnets called magnetic dipoles. Each dipole has both North pole and South pole.



The magnetic dipoles group themselves in what we call the Domain.

In each domain, the magnetic dipoles are parallel and point in the same direction.

(a) For a magnet or a magnetized material, all dipoles in all the domains are arranged (aligned) facing in the same direction.

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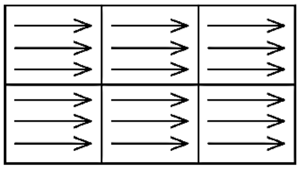
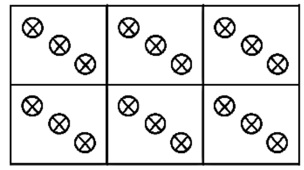
Examples

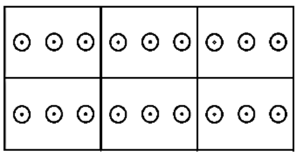
(i)



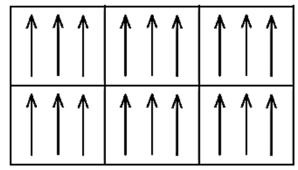
(ii)



(iii)



(iv)

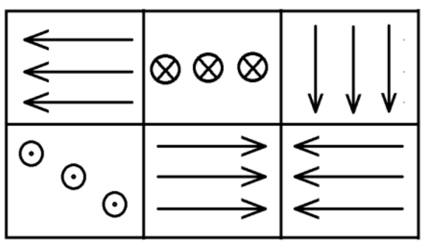


KEY

⊙ Means magnetic field moving out of 'this' paper perpendicularly.

⊗ Means magnetic field moving into (entering) into 'this' paper perpendicularly.

(b) For a magnetic material which is not magnetized, the dipoles in the different domains are in different directions.



Un-magnetised magnetic material

EXPLANATIONS GIVEN BY THE DOMAIN THEORY

The domain theory is used to explain the following;

- Magnetization and magnetic saturation
- Breaking a magnet
- Demagnetization

1. Magnetization and Magnetic saturation.

When a magnetic material is being magnetized, all magnetic dipoles begin to re-arrange (re-align) themselves parallel to one another. When all the dipoles are in the same direction, the magnetic strength cannot be increased any further and the magnetized material or magnet has become magnetically saturated. This point or state is called magnetic saturation.

Magnetic saturation is the state reached by a magnetized material when the strength of its magnetism cannot be increased any further.

At this state, all the dipoles in all the domains point in the same directions.

Note: At saturation point, the strength of the magnet has reached its maximum value.

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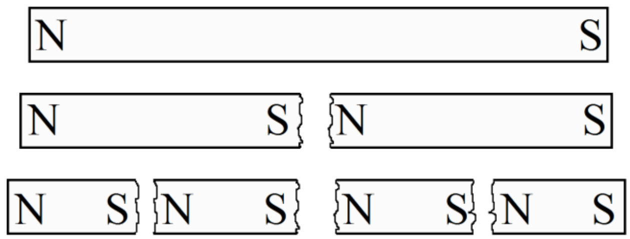
2. Breaking a magnet.

When a magnet is broken or cut into two pieces, each fracture surface exposes the ends of dipoles which were pointing in the same direction with south pole (S) ends on one surface and north pole ends (N) on the other surface.

Thus, each piece remains a magnet and has both the North pole and the South pole.

If the resulting pieces are further broken, smaller magnets are obtained each with the North and South poles.

So, even the smallest particle which can be obtained from a broken magnet is also a magnet. This confirms the existence of magnetic dipoles.



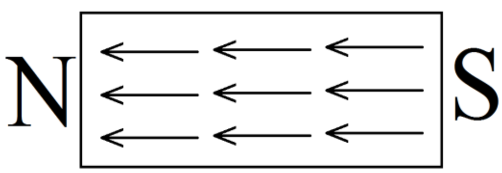
NOTE: The process of breaking a magnet does not disorganize the arrangement (alignment) of dipoles, so it does not cause demagnetization.

3. Demagnetization

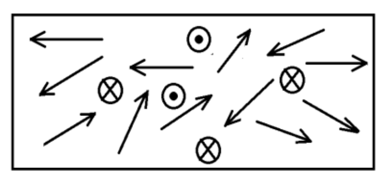
During demagnetization by any method, the arrangement of magnetic dipoles is disorganized which reduces the strength of the magnet.

When all the dipoles are randomly arranged, then the magnet is completely demagnetized.

(i) Magnetised material



(ii) Demagnetised material



A demagnetized material has no North and South poles.

NOTE

(i) When a ferromagnetic material is placed in a strong magnetic field, all its dipoles in all the domains get aligned in the same direction of the field and the material becomes a strong magnet.

(ii) When a paramagnetic material is placed in a strong magnetic field, its molecular magnets become partially aligned in the same direction of the field and the material becomes a very weak magnet.

(iii) When a diamagnetic material is placed in a strong magnetic field, the orbiting of electrons in the material is disturbed and field inside the material is just weakened.

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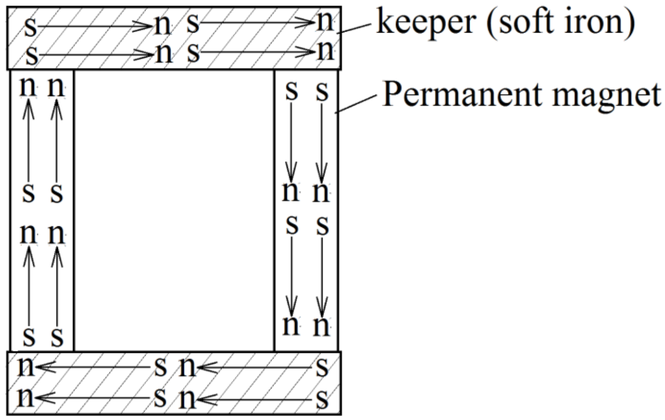
STORING MAGNETS (THE MAGNETIC KEEPERS)

When a magnet is left alone, self-demagnetization occurs and the magnet becomes weaker with time. This is due to the free like poles of the dipoles near each other that repel and disturb the arrangement of the dipoles. This disorganizes the dipoles and reduces the strength of the magnet.

To prevent self-demagnetization, bar magnets are stored in pairs with unlike poles near each other and pieces of soft iron called keepers across their ends.

The keepers become strong induced magnets and so a closed loop or chain is formed in which all magnetic dipoles link up in a stable pattern with no free like poles.



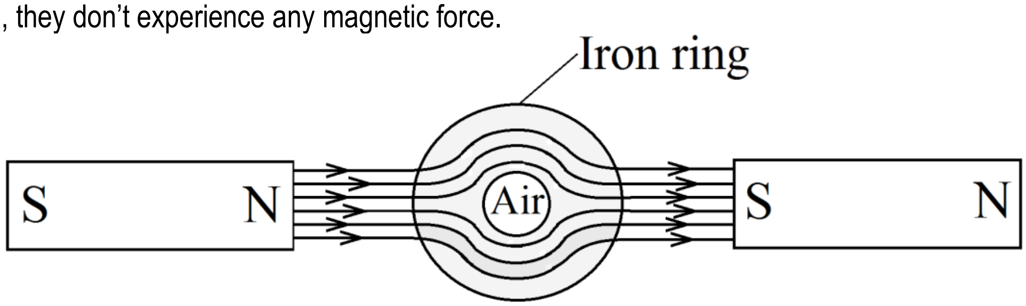
MAGNETIC SHIELDING OR SCREENING

This is the protection of a region or point against unwanted magnetic field.

When a piece of soft iron is placed in a magnetic field, all the magnetic field lines tend to be attracted to pass through it than to pass through air. This is because the soft iron is more permeable to magnetism than air.

Magnetic permeability is the concentration of magnetic flux through a material placed in a magnetic field.

If a soft iron ring is placed in a magnetic field, all magnetic lines of force pass through the iron and not through the air in the middle. The space inside the iron ring is said to be shielded from or screened off the magnetic field. If magnetic materials such as iron nails or steel nails/pins are placed in the middle of the ring, they don't experience any magnetic force.



APPLICATIONS (USES) OF MAGNETIC SCREENING

- It is applied in video tubes.
- It is applied in watches. The watches are enclosed in thick iron boxes to avoid being affected by magnetic fields.

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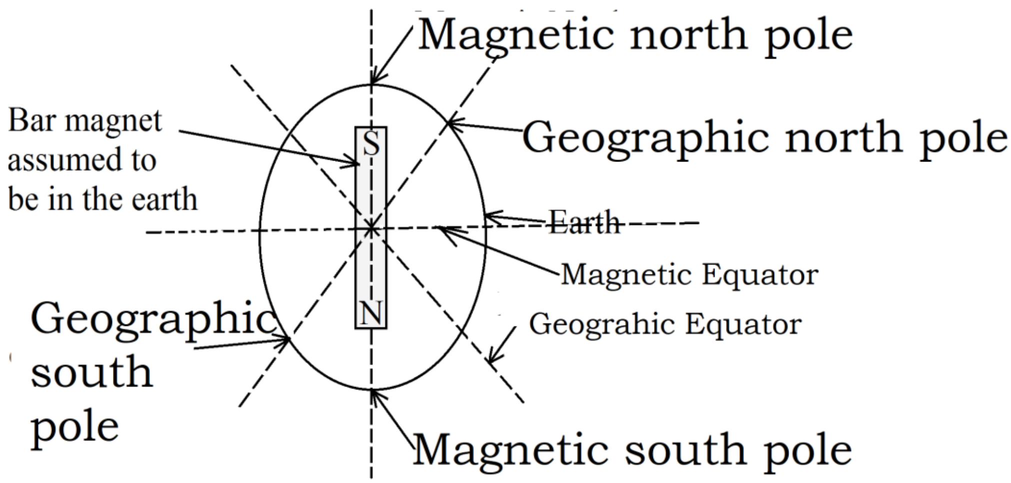
THE EARTH AS A MAGNET

The earth behaves as though it contains a small bar magnet inclined at a small angle to its axis of rotation with its South pole in the northern hemisphere and its North pole in the southern hemisphere. This is why the earth's lines of force run/move towards the northern hemisphere to the south pole of the earth's magnet from the north pole of the earth's magnet in the southern hemisphere.

It is also the reason why a freely suspended bar magnet rests in the north-south direction with its north pole is in the northern hemisphere where it is attracted to the south pole of the earth's magnet and its south pole is in the southern hemisphere where it is attracted to the north pole of the earth's magnet.



DEFINITIONS

1. The magnetic meridian.
   Magnetic meridian is a vertical plane containing the magnetic axis of a freely suspended magnet at rest under the action of the earth's field.
   OR
   The magnetic meridian at any place is a vertical plane containing the line joining the earth's magnetic poles.

2. The geographic meridian.
   Geographic meridian at a place is the plane containing the place and the earth's axis of rotation.
   OR
   The geographic meridian at a place is the plane containing the line joining the earth's geographical poles.

3. Angle of declination Or magnetic declination
   This is the angle between the geographic and magnetic meridians.

4. Angle of inclination Or angle of dip.
   It is the angle between the earth's magnetic flux direction and the horizontal.

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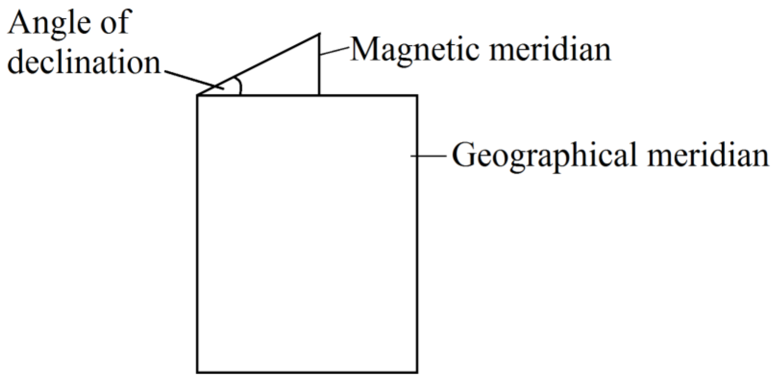
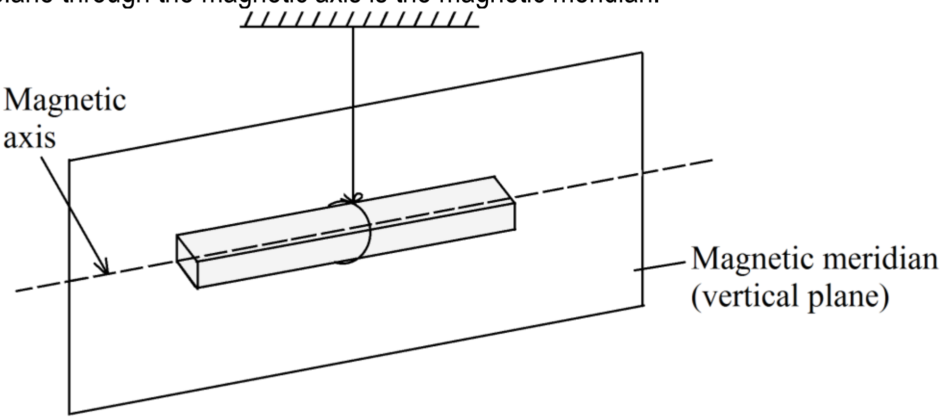


AN EXPERIMENT TO DETERMINE THE EARTH'S MAGNETIC MERIDIAN

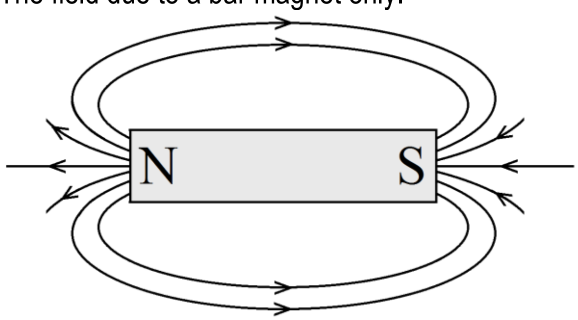
A bar magnet is suspended freely using a thread or string.
It is then allowed to come to rest.
The vertical plane through the magnetic axis is the magnetic meridian.



RESULTANT MAGNETIC FIELD PATTERN OF THE EARTH AND A BAR MAGNET

When a bar magnet is placed horizontally, the field around it is a combination of its field and the earth's field.
The resulting pattern depends on the direction of the bar magnet.

i) The field due to a bar magnet only.



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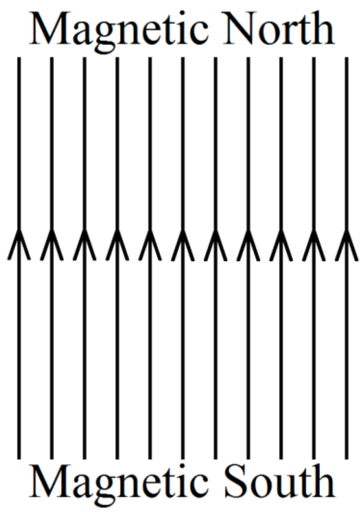
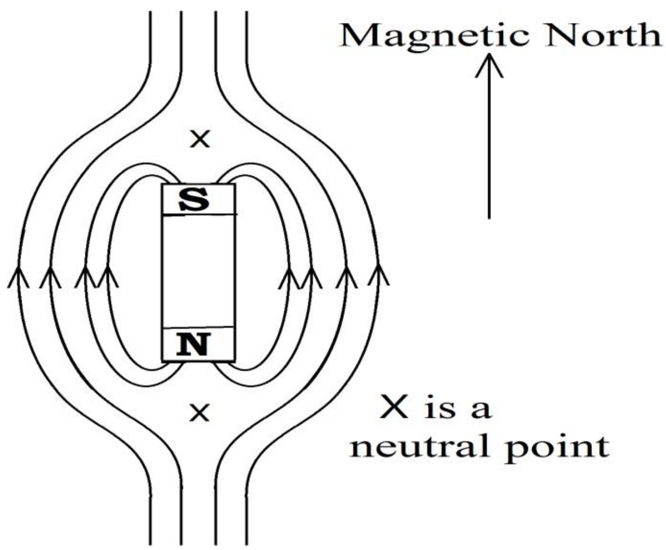
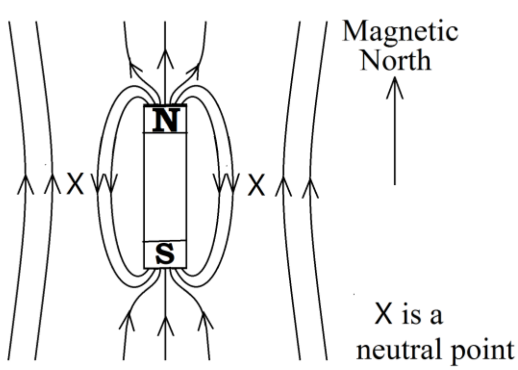
ii) Magnetic field pattern of the earth's magnet.



iii) Resultant field pattern of a bar magnet in the earth's field with its South pole pointing Northern direction



iv) Resultant magnetic field pattern of a bar magnet in earth's field with its North pole pointing Southern direction.



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