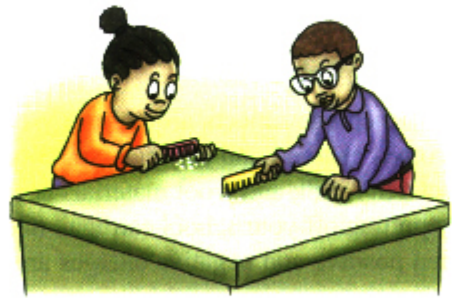
10 ELECTRIC CHARGE



Application of Electric Charge

Electricity is very important; without it, life will be difficult. Imagine how our cities will look like if there is no electricity. We are so familiar with electricity that we do not worry about its existence, nature and source. Electric charge is a very important property of matter; therefore, a good understanding of its nature will help us to make better use of it. Though, we are not sure what an electric charge is, we understand its nature.

OBJECTIVES

At the end of this topic, students should be able to:

- charge a body by friction, conduction (contact) and induction;
- identify bodies charged either similarly or oppositely;
- show how an electroscope is used to:
  - detect the presence of charge;
  - determine the magnitude of electric charge;
  - distinguish between good, poor and bad conductor of electricity.

Atom is the source of electric charge

Matter consists of tiny particles called atoms. An atom consists of three basic particles **proton, neutron** and **electron.**

- The proton has a positive charge.
- The electron has a negative charge.
- The neutron has no charge.

The protons and the neutrons together form the nucleus of an atom. The nucleus is at the centre of an atom while the electrons move round it at a very high speed. In an atom, the number of protons balances the number of electrons making an atom electrically neutral. When an atom gains electrons, it will have more electrons than protons. Such an atom is negatively charged. If an atom loses electrons, it becomes a positively charged atom. An atom is therefore the source of both positive and negative charges.

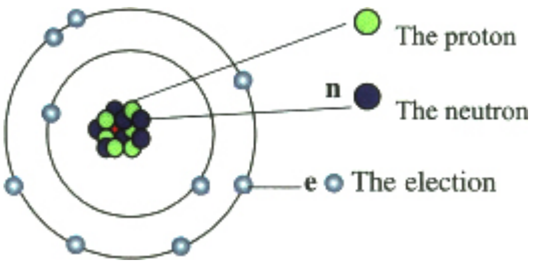


Figure 10.1 Structure ofan atom

Charging objects

We can charge objects around us. When you comb your hair with a plastic comb, the comb becomes charged and can pick small pieces of paper. The charge on the comb is called **static electricity.** Silk and wool materials become charged during the harmattan and stick to the body. Try putting off your school cardigan in the harmattan, you will hear cracking sound. This occurs when positive and negative charges are pulled apart.

Static electricity

The charge on a charged object is called **static electricity.** There are two types of static electricity:

1. Positive electricity: A positively charged body has positive electricity. When a glass (Perspex) rod is rubbed with silk material, it gives out electrons to the silk to become positively charged. The silk accepts electrons to become negatively charged.

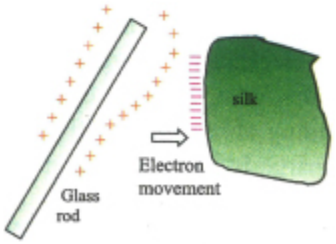


Figure 10.2 Charging silk negatively

2. Negative electricity: A body with excess electrons has negative electricity. A plastic (polythene) material gains more electrons if it is rubbed with fur (wool) cloth. Rubbing or friction makes the polythene or ebonite accepts electrons from the fur. The fur or wool loses electrons to become positively charged. Objects become charged when they gain or lose electrons.

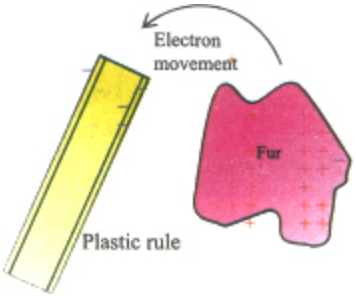


Figure 10.3 Charging fur positively

The laws of electric charges

Electric charges exert force of attraction or repulsion on each other. The strength of the force depends on the size of the charges and the distance between them. The nature of the force is determined by the nature of the charges.

- When two unlike charges (one positive and the other negative) are brought near each other, they attract.
- When two like charges (two positive or two negative charges) are brought near each other, they repel.

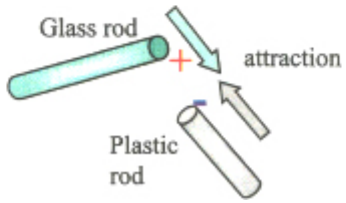


Figure 10.4 (a) Unlike charges attract

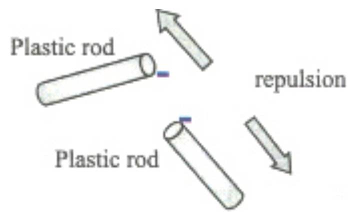


Figure 10.4 (b) Like charges repel

We can summarize the observation above into a law of electrostatic charges.

The law of electrostatic charges states that like charges repel and unlike charges attract

Conductors and insulators

All materials are classified as conductors or insulators. Metals are **good conductors** of electricity because they permit electrons to pass through them with ease. This is because the outer electrons of the atoms of metals are bound loosely to it. Good conductors like metals do not store up charges because the charges are conducted easily through the metals to the ground if they are earthed.

Non-metals are bad conductors of electricity. They present strong resistance to the passage of electrons and are called **insulators.** Examples of insulators are plastic, rubber, silk, cotton, dry paper, dry air, dry wood, etc. Some materials fall between good and bad conductor; they are called **poor conductors.** Poor conductors of electricity include wet wood, concrete floor, stone, human body, pure water, etc.

The electroscope

The electroscope is used to:

- detect the presence of a charge (to find out if there is a charge on the body or not);
- determine the nature of the charge on the body (to find out if the charge on the body is positive or negative);
- distinguish between conductors and insulators.

Description of electroscope

The electroscope is made up of three essential parts, the metal cap that is joined to the metal rod (stem); a metal foil (gold leaf) attached at the end of the metal stem; the metal foil (gold leaf) is the only part of the electroscope that moves. The metal foil is put inside a glass container to shield it from drought and the stem is supported with an insulator. The electroscope is protected from the outside charges by a metal placed around its neck.

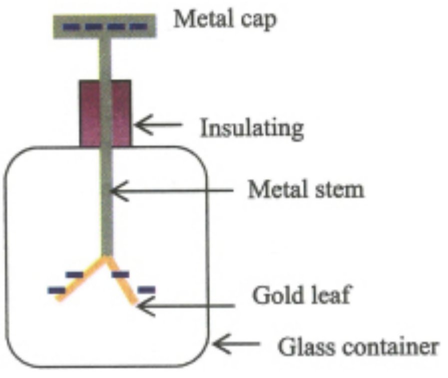


Figure 10.5 The electroscope

Detection of charges

To detect the presence of a charge on a body, a charged body is brought near the metal cap of an electroscope. The metal foils (gold leaves) open or diverge; the diverging of the leaves indicates the presence of charges on the body. The degree of the divergence is a measure of the amount of charges on the body.

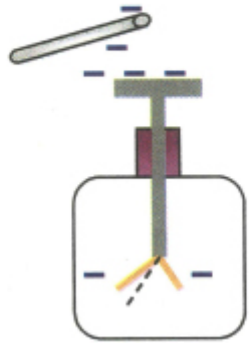


Figure 10.6 Detection of charge

Determining the nature of a charge

A charged electroscope is used to find out if the charge on the body is positive or negative. The following steps show how to do this.

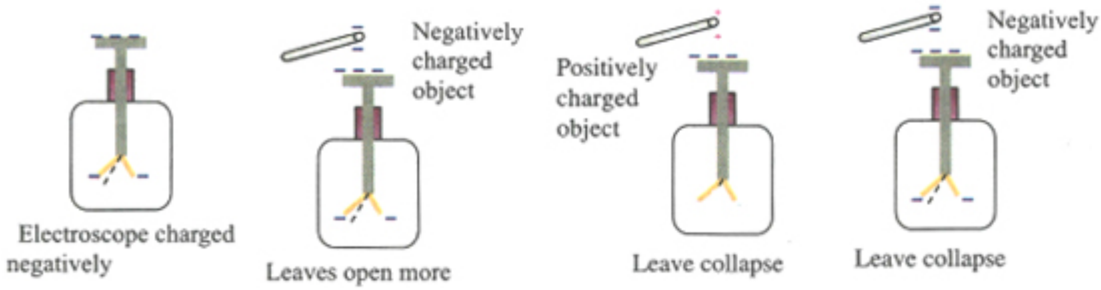


Figure 10.7 Detecting the nature of charge

(i) The electroscope is charged positively or negatively.

(ii) If the electroscope is charged negatively and a rod with negative charges brought near the metal cap, the metal foils open more (the divergence of the leaves increases).

(iii) If a positively charged rod is brought close to the metal cap, the metal foil falls (the leaf divergence reduces). An uncharged or neutral object produces the same effect as the positively charged rod.

(iv) The fall or decrease in the leaf divergence is not used to determine the nature of the charge on a body.

(v) If the leaves open more, the charge on the rod is the same as the charge on the electroscope; therefore, the only true test for the nature of the charge on a body is the increase in the opening of the leaves.

The divergence of the leaves increases because more charges are pushed down to the leaves by the repulsive force of the like charges between the metal cap and the rod. To test for a positive charge, first, charge the electroscope positively, then place the charged rod near the cap of the electroscope; an increased divergence of the leaves means that the rod is positively charged.

Difference between conductors and insulators

We can differentiate between **good, poor** and **bad conductors** by touching them on the cap of a charged electroscope.

- If the leaf falls **suddenly** (fast) the material is a good conductor.
- If the leaf falls **slowly,** the material is a poor conductor.
- If there is no **change** in the leaf divergence, the material is a bad conductor.

The leaf falls quickly for a conductor because it allows charges to leak through it rapidly. Insulators do not permit electric charge to leak through them, therefore, the leaves do not show any change in its divergence. To charge a conductor, it must be supported on an insulator to stop charges from leaking to the ground.

Summary

- An atom is the source of electric charge.
- An atom consists of three basic particles; proton, neutron and electron.
- If an atom loses or gains electrons, it becomes charged.
- The charge on an object is called static electricity. The two types of static electricity are positive and negative electricities.
- The law of electrostatic charges states that like charges repel and unlike charges attract.
- Good conductors like metals do not store up charges because the charges are conducted easily through the metals to the ground if they are earthed.
- The electroscope is used to detect the presence of a charge, determine the nature of the charge on the body and distinguish between conductors and insulators.
- The only true test for the nature of the charge on a body is the increase in the opening of the leaves.
- The collapse of the leaf for a conductor is because it allows charges to leak through it rapidly.
- Insulators do not permit electric charge to leak through them, therefore, the leaves do not show any change in their divergence.

Practice questions 10a

1. Explain the term static electricity and name two types of static electricity.
2. (a) Explain how an atom is the source of charges.
   (b) Name the three basic particles of an atom and state the

nature of charge on each of them.

3. (a) Explain how a normal atom can be charged.
   (b) What part does an electron play in charging of an object?
4. A polythene rod is rubbed with fur, state with reason, the nature of the charge on the polythene and silk at the end of rubbing.
5. State the law of electrostatic charges. Outline the steps you will take to prove the truth of the law.
6. (a) What is an electroscope? State **three** uses of an electroscope.
   (b) Describe how you will use an electroscope to find out the nature of charge on a body.
7. What is (i) a conductor (ii) an insulator?
   (b) How can you use an electroscope to differentiate between the two?
8. A negatively charged rod is brought near the cap of a negatively charged electroscope. Explain why the leaves divergence increases.
   (b) Explain why the leaves collapse when the electroscope is touched with a finger.
9. Explain why removing a pullover in cold dry season can produce cracks and tiny sparks.
10. Amina rubbed a Perspex rod with wool, brings it near the cap of an electroscope and the leaf falls. Identify the charges on the wool, the electroscope and the Perspex rod.
11. Explain why it may not be easy to charge an earthed conductor.

ELECTROSTATIC INDUCTION

OBJECTIVES

At the end of this topic students should be able to:

- explain electrostatic induction;
- charge a body by friction, conduction (contact) and induction;
- charge electrophorus and use it to generate positive charges.

(i) Rub a plastic ruler or biro on your hair or wool.

(ii) Bring the rubbed plastic ruler or biro close to small pieces of papers.

(iii) Notice that papers jump and stick on the charged plastic ruler or biro.

The plastic ruler or biro gains negative charge after rubbing. When it is brought close to the small pieces of paper, the negative charges on the plastic ruler repel the negative charges on the papers and attract the positive charges. The attractive electrostatic force between the negative charges of the plastic ruler and the positive charges of the paper draws the paper towards the charged plastic ruler or biro.

A balloon rubbed on a dry hair or with wool sticks to the wall. This happens because the negative charge on the balloon repels some of the electrons on the wall away from its surface. The surface of the wall is charged positively and attracts the negatively charged balloon.

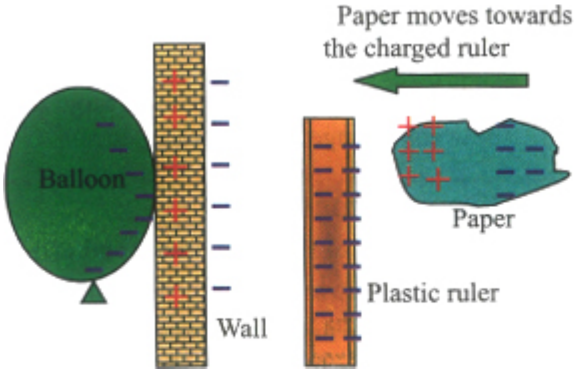


Figure 10.8 Electrostatic induction

The charging of an object when a charged body is brought close to it is called electrostatic induction.

The wall and the pieces of paper are charged by induction. The separated charges on them are called **induced charges.** The balloon and the plastic ruler are called **inducing objects. Charges are induced on an object anytime a charged object comes close to it.**

Different ways of charging an object

An uncharged object can be charged in three different ways:

a. Friction or rubbing

An object is charged by friction if it is rubbed with another. Rubbing transfers electrons from one object to the other. When a Perspex (glass) rod is rubbed with silk, the rod loses electrons to the silk to become positively charged. The Perspex (glass) rod is said to be charged by friction.

b. Conduction or contact

An uncharged body may be charged by bringing it in contact with a charged object. Charges are transferred from the charged object to the uncharged one. This method of charging is known as **conduction** or **contact.** If a rod with negative charges is used, the neutral body gains negative charges to become negatively charged. Charging by conduction gives the neutral body the same charge on the charged object.

c. Charging by induction

A neutral object can be charged by bringing a charged body close to it. The process of charging an object without touching it with the charging body is called **induction**.

(i) Charging two objects by induction

Two metal spheres A and B may be charged by induction as follows:

- The two metal spheres A and B supported by an insulating base are brought in contact.
- A negatively charged inducing rod (R) is placed near the sphere A. Electrons are repelled from sphere A to sphere B by the negative charges on the inducing rod (R). Sphere A becomes positively charged while the sphere B becomes negatively charged.
- Without removing the inducing rod, the spheres A and B are separated.
- Lastly, the inducing rod is removed. The electrons cannot return to their positions again, therefore the metal sphere A becomes positively charged while the sphere B becomes negatively charged.

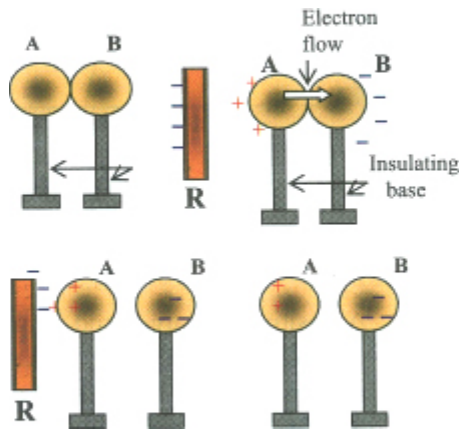


Figure 10.9a Charging two conductors by induction

The student should note the following important facts:

1. The sphere nearest to the inducing rod gain charge with sign opposite to the charge on the inducing rod. If the charge on the inducing rod is positive, then sphere A will gain a negative charge.
2. Removing the inducing rod before separating the spheres will allow the electrons to return to sphere A.
3. The insulating stand or support stops the electrons from leaking to the ground.

(ii) Charging one object by induction

A single object can be charged by induction. The following steps outline how this is done.

- The metal sphere is supported on an insulating stand. This stops the electrons from leaking to the ground.
- An inducing rod with negative charges is positioned near the sphere. The positive charges are attracted while the electrons are repelled to the opposite end.

- The metal sphere is earthed by touching it with a finger; electrons are conducted through the finger to the ground.
- The finger is removed from the sphere.
- The inducing rod is finally removed; the positive charge spreads to other parts of the sphere. The sphere becomes positively charged.

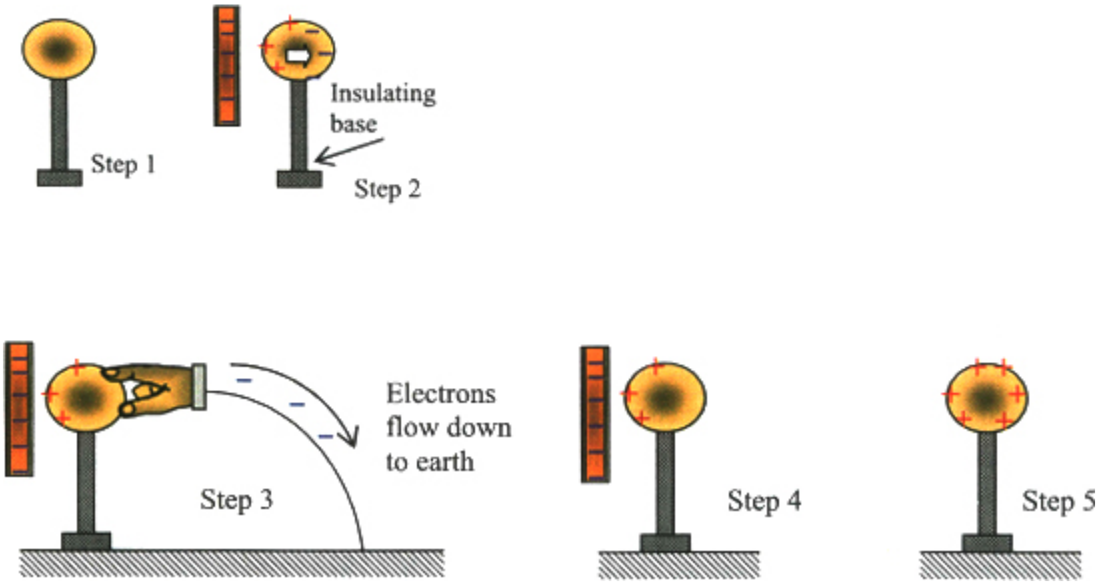


Figure 10.9b Charging one conductor by induction

(iii) Charging an electroscope by induction

1. A positively charged rod is placed near the cap of the electroscope. The rod repels the positive charges down to the leaves while the electrons are attracted.
2. The cap of the electroscope is earthed by touching it with a finger; electrons flow from the earth through the finger to cancel out the positive charges.
3. The finger is removed first; then, the negatively charged rod. The negative charges on the cap spread to the leaves making the electroscope to be negatively charged.

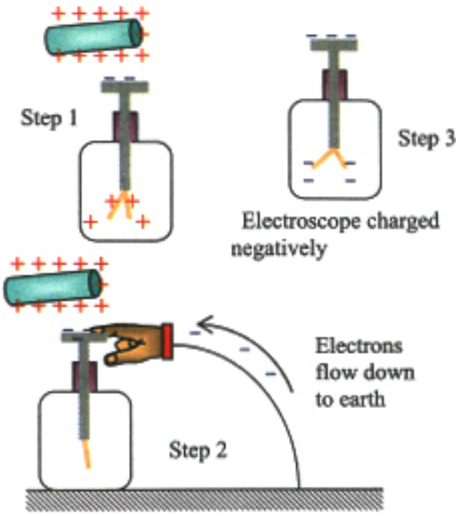


Figure 10.10 Charging electroscope by induction

The electrophorus

The electrophorus is an electrostatic generator. It is used to generate and store up positive charges.

Description: The electrophorus consists of a metal disc with a handle made from an insulator and a polythene slab.

Charging an electrophorus The polythene slab is first charged negatively; when the metal disc is placed near the slab, the slab attracts the positive charges while the electrons are repelled to the opposite side. The disc is earthed by touching it with a finger; electrons are conducted to the ground leaving the disc positively charged.

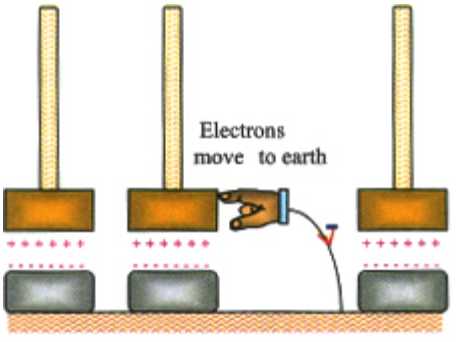


Figure 10.11 Charging electrophorus by induction

Using the stored energy

The energy stored by the electrophorus is released as an electric spark when it is brought near a gas or when a finger is brought close to it. The electrical energy of the spark comes from the mechanical work done during charging when the positive and negative charges are separated.

Summary

- The charging of an object when a charged body is brought close to it is called electrostatic induction.
- Charges are induced on an object anytime a charged object comes close to it.
- Different ways an object can be charged are friction or rubbing, conduction or contact and induction.
- An object charged by induction, gains charge with sign opposite to the charge on the inducing rod.
- The electrophorus is an electrostatic generator. It is used to generate and store up positive charges.

Practice questions 10b

1. Describe **two** ways to charge a neutral object negatively.
2. Explain why a conductor may not be charged when it is held with a hand but an insulator can be charged under the same condition.
3. (a) Outline the steps you will take to charge an electroscope negatively by induction.
   (b) A conductor is touched on the cap of a charged electroscope, state with reason what happens to the leaves of the electroscope.
4. (a) Explain the following terms;
   (i) electrostatic induction (ii) induced charge
   (b) Describe how to charge a single conductor negatively by induction.
5. What is an electrophorus? Explain why a spark is produced when a finger is held close to an electrophorus.
6. A positively charged rod is held near the cap of an electroscope.
   (a) Explain why the leaves diverge more.
   (b) What is the nature of the charge on the electroscope?

7 Explain why;
   (a) a rubbed plastic pen attracts small piece of papers;
   (b) a charged balloon sticks to the wall;
   (c) rubber shoes attract dust after walking a long distance.

CHARGE DISTRIBUTION

OBJECTIVES

At the end of the topic, students should be able to:

- use proof plane and the electroscope to find the charge distribution on a conductor;
- explain the point action of a point and the working of a lightning conductor.

To study how charges are distributed on a conductor, a gold leaf electroscope and a proof plane are used.

1. The proof plane

The proof plane is a small metal disc with a long handle made with an insulator. When the disc is touched on the conductor, it collects the charge in contact with it. The number of charges collected at the point of contact increases as the surface charge density (the number of charge per unit area) increases.

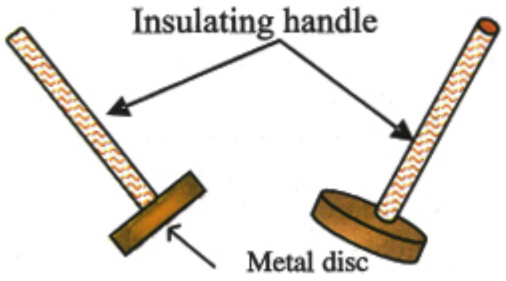


Figure 10.12 The proof plane

2. Charge distribution on a pear-shaped conductor

Proof plane is used to collect charge from different parts of the conductor and transfer them to the electroscope. The increase in divergence of the leaf of the electroscope measures the surface charge density at that point.

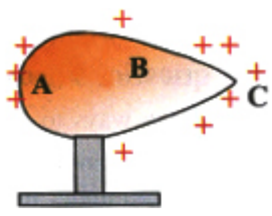


Figure 10.13 Charge distribution on a pear shape conductor

The surface charge density is the number of charge in a unit area.

Experiments with proof plane and electroscope confirm that the charge distribution on a pear -shaped conductor is not uniform. The surface charge density for a pear-shaped conductor varies along its surface depending on the sharpness of the curve. The charge concentration (surface charge density) is greatest at C where the surface is sharply curved and least at B where surface is almost flat. We summarize by saying that:

Charges tend to stay more or concentrate where the surface curves sharply or at a point.

3. Charge distribution on a uniformly shaped conductors

The charge distribution on conductors with uniform shapes like a sphere is uniform. The charge density is the same on every part of the conductor.

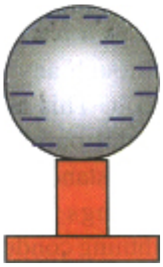


Figure 10.14 Charge distribution on a sphere is uniform

4. Charge distribution of a hollow conductor

Test with proof plane reveals that **charge stays only on the outside surface of hollow conductors.** The proof plane picks no charge when it is placed inside a hollow conductor therefore, **the net charge inside a hollow conductor is zero**.

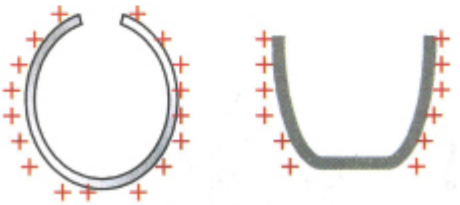


Figure 10.15 Charge stays only on the outside of a hollow conductor

Discharge action of a point

Charges tend to concentrate at a point. The surface charge density at the point is very high that some charges are repelled away from the point. If the point is charged positively, it will attract electrons from surrounding air molecules leaving them positively charged. The positively charged air molecules are repelled at a very great speed away from the point. The motion of the receding charged molecules creates a current of air or breeze called **electric wind.** As the positively charged molecules move away from the point, they knock out electrons from nearby air molecules making them to be ionized. The electrons are discharged at the point (i.e. the point attracts the electrons and conducts them from the neighbouring air molecules to the ground). This action of a point is used in lightning conductors to discharge electrons from the cloud; protecting tall buildings from thunderstorm.

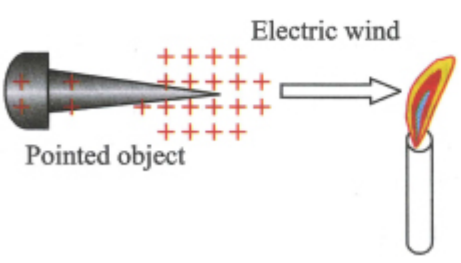
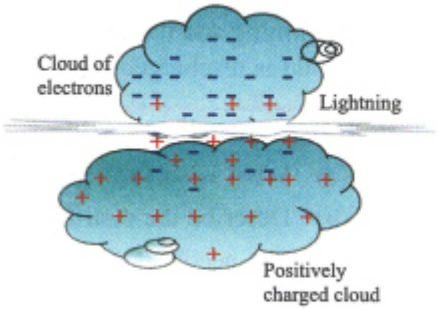


Figure 10.16 Actions at a point

Lightning and lightning conductor

When you pull off your school pullover in a dark room during cold dry season cracks and sparks are produced. The crack is thunder and the spark is lightning in a small scale.

Lightning and thunder are sparks and cracks produced in the atmosphere when a negatively charged cloud is discharged rapidly by a positively charged cloud.



Sudden separation of a positive and negative charge also produces lightning and thunder.

During thunderstorm, some electrons may not be discharged by the positive cloud, these descend to the ground passing through any material, which offers the least resistance to it. This is very dangerous as it can cause damage to tall buildings or trees because they provide smallest resistance for the electrons to pass. To protect tall buildings and places at high risk of thunderstorm, lightning conductors are sited at the tallest point of the building.

A lightning conductor is made up of **pointed spikes** connected to a **copper strip.** The metal spikes are sited at the tallest point of a building, while the copper strip is connected to the ground. During thunderstorm, electron cloud that was not discharged by the cloud of positive charge passes over the spike. Electrons on the spike are repelled by the positively charged cloud and flow through the copper strip to the ground. The metal spike becomes positively charged. The high charge density on the spike repels positive ions away from the spike towards the descending electrons and neutralizes them. As the positive charge moves upward at a great speed, they collide with air molecules knocking out electrons from them. The electrons produced when the air molecules were ionized are attracted by the spike and conducted through the copper strip to the ground. The spike repels the ionized air molecules upward to assist in discharging the electron cloud. This helps to stop lightning and protects tall building from being struck by thunderstorm.

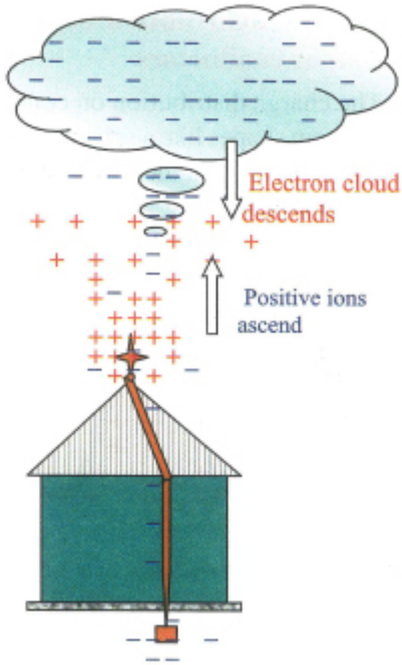


Figure 10.17 Lighting conductors protecting a tall building from thunderstorm

Summary

- The surface charge density is the number of charge in a unit area.
- Charge tends to stay more or concentrate where the surface curves sharply or at a point.
- The charge distribution on conductors with uniform shapes like a sphere is the same round the conductor.
- Charge stays only on the outside surface of hollow conductors. The net charge inside a hollow conductor is zero.
- Electric wind is the breeze produced by the motion of the receding charged molecules.
- Lightning and thunder sparks are produced in the atmosphere when a negatively charged cloud is discharged rapidly by a positively charged cloud.

Practice questions 10c

1. (a) What is surface charge density?
   (b) Describe the distribution of charge on a charged pear-shaped conductor.
   (c) If a needle is fixed on a charged conductor, what effect will it have on the charge distribution?
2. (a) Describe the action of points on a charged conductor.
   (b) How is the discharging action of a point used to protect

buildings from thunderstorm?

3. (a) What is lightning?
   (b) Describe a lightning conductor and explain how it is used to prevent lightning from destroying buildings during storm.
4. Explain each of the following occurrences.
   a. It may be risky to lift an umbrella in a storm.
   b. It is safer to remain inside a car during thunderstorm than under a tree.
   c. Lightning conductors are sited at the tallest point of a building.
5. Explain the following events.
   a. Nylon dresses crackle when you undress.
   b. In a dry weather, people walking on a nylon carpet may get shocked if they touch a metal door.
   c. People sometimes get a shock if they come down from a car.
   d. Light is produced if you slide your hand over a fluorescent tube or nylon in a dark room.
6. (a) What is an electric wind? How is it produced by a pointed conductor?
   (b) Explain the part it plays in discharging an electron cloud.
7. Which of the following is **not** correct about a hollow conductor?
   A. The total charge inside a hollow conductor is zero.
   B. All the charge resides on the outside.
   C. Most of the charge stays on the inside of a hollow conductor.
   D. Charge density is more at the sharp edges of a hollow conductor.

Past questions

1. A positively charged glass rod is placed near the cap of a positively charged electroscope. The divergence of the leaf is observed to
   A. decrease.
   B. increase.
   C. remain the same.
   D. increase and collapse immediately.

WASSCE

2. Which of the following items can be used to compare the relative magnitudes of electric charge on two bodies?
   A. Ebonite rod
   B. Gold leaf electroscope
   C. Proof planes
   D. The electrophorus

WASSCE

3. A negatively charged rod is brought near the cap of an

electroscope. The cap is momentarily earthed the charge near to it. The rod is then removed. Which statement is correct?

A. The cap will be positively charged and the leaf will be negatively charged.

B. The cap will be negatively charged and the leaf will be positively charged.

C. The cap and the leaf will be positively charged.

D. The cap and the leaf will be negatively charged.

E. The cap and the leaf will become uncharged.

NECO

4. Two uncharged conductors, **X** and **Y**, are placed in contact with each other. A negatively charged rod is brought close to **X**, **X** and **Y** are then separated while the rod is still held close to them. What type of charge will appear on **X** and **Y**?

A. **X** will be positive while **Y** will be negative.

B. **X** will be negative while **Y** will be positive.

C. Both **X** and **Y** will be positive.

D. Both **X** and **Y** will be negative.

WASSCE

5. In using a gold leaf electroscope to determine the nature of electric charge on a body, it is observed that when the charges on the body and electroscope are the same, the divergence of the leaves

A. decreases.

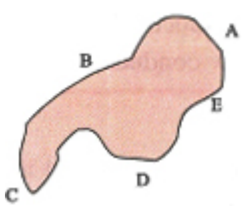
B. increases.

C. remains unchanged.

D. disappears.

WASSCE 2001

6. Which part of the conductor below will have the greatest charge density?



NECO

7. A rod is brought near the cap of a negatively charged electroscope. It is observed that the leaf of the electroscope diverges farther showing that the rod is

A. positively charged.

B. not charged.

C. an insulator.

D. negatively charged.

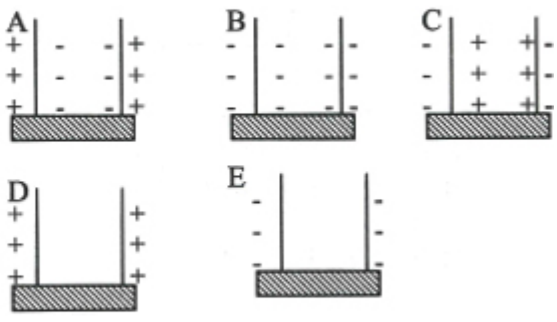
WASSCE

8. Which of the following indicates the correct sequence of steps in charging a gold leaf electroscope by induction?
   I Removing the ebonite rod.
   II Bringing a negatively-charged ebonite rod closed to the cap.
   III Earthing the cap.
   IV Disconnecting the earthing.
   A. III, II, I and IV
   B. II, I, III and IV
   C. III, IV, II and I
   D. II, III, IV and I
   E. III, IV, I and II

WAEC

9. A negatively charged rod is brought near the cap of a gold leaf electroscope. The cap is earthed momentarily while the rod is held near it. The rod is then removed. Which of the following is correct?
   A. The cap will be positively charged and the negatively charged leaves will diverge.
   B. The cap will be negatively charged and the positively charged leaves will diverge.
   C. The cap and the leaves will be positively charged.
   D. The cap and the leaves will be negatively charged.
   E. The leaves will not diverge because the cap has been earthed.

10. A positively charged sphere is suspended inside a hollow can placed on an insulating base. If the can is momentarily earthed and the charge sphere is then withdrawn, which of the following diagrams best represents the charge distribution on the can after this process?



11. If the leaves of a positively charged electroscope collapse completely as an object is brought near the cap of the electroscope. The object possesses
   A. an equal amount of positive charge.
   B. less amount of negative charge.
   C. no charge.
   D. a positive charge.

E. equal amount of negative charge.

WAEC J

12. The sign of a charge on a charged glass rod may be determined with
    A. a charged electroscope.
    B. an uncharged electroscope.
    C. a galvanometer.
    D. an electrometer.

JAMB

13. An ebonite rod rubbed with fur attracts a glass rod rubbed with silk because
    A. ebonite rod has a negative charge while glass has a positive charge.
    B. ebonite rod has a positive charge while glass has a negative charge.
    C. both have negative charges.
    D. both have positive charges.

JAMB

14. When an ebonite rod is rubbed with fur, it has
    A. no charge at all
    B. a negative charge
    C. a positive charge
    D. negative and positive charge.

JAMB

15. When a biro rubbed on a dry silk cloth is moved very close to a piece of paper on dry table, the pen is found to pick up the paper. This is because
    A. both the pen and the paper are magnetised
    B. the pen is magnetized but the paper is not.
    C. the pen is charged while the paper is magnetized.
    D. Both the pen and the paper are charged.

JAMB


Sade, look at my comb! I used it to comb my hair and now it can pick pieces of paper!