

Static Electricity

LEARNING OUTCOMES

- Static charges
- Origin of charges
- Charging an object: by friction, conduction, and induction
- The gold-leaf electroscope
- Flow of electrons
- Atmospheric electricity
- Lightning conductor

You might have studied about current electricity in detail in class 7. Electricity is a broad term given to a wide range of phenomena from lightning that we see in the sky to lighting a bulb. You know that almost all the gadgets and appliances work by electricity. It lights up bulbs in our houses, makes our fans work, runs our refrigerators, provides us warmth through room heaters, and helps us in many other ways.

This kind of electricity that makes our household appliances work is called *current electricity* because here electric charges are in motion. But, sometimes charges can be separated from neutral bodies and cause an imbalance of charges in them. It is then called *static electricity*. In fact, static electricity was the first kind of electricity to be discovered.

In this chapter, you will study about static electricity, how objects can acquire electric charges, and its practical applications. Let us observe the following three figures before studying what static electricity means.



(a)



(b)



(c)



Have you ever felt a sharp tingle when you walk across a rug and touch a metal door knob in dry weather? Read the chapter further to know why this happens.

Have you ever tried doing what the girl in the above figures is doing? What do you observe? You will observe that when a plastic ruler is brought close to some bits of paper, the bits don't get



C A Coulomb
(1736–1806)

C A Coulomb made enormous contributions in the field of static electricity. He developed the theory of attraction and repulsion between charged bodies.

attracted to the ruler (a); when that ruler is rubbed against hair (b) and then brought close to the same bits of paper, they get attracted to the ruler (c). Can you explain why this happens?

When the ruler is rubbed against hair, it acquires an electric charge and a force is produced in it due to which it attracts the bits of paper. This force is called *electrostatic force* and forms the basis of *static electricity*.

The branch of physics that deals with the study of static electricity which involves electric charges, the force between them, and their behaviour is called *electrostatics*.

How does the ruler get charged? What is the nature of that charge? What is the force that attracts those bits of paper? Is that force always attractive or sometimes repulsive? Does our atmosphere also have electric charges? You will get answers to all these questions as you read this chapter further.

ACTIVITY

Aim: To study the forces of attraction and repulsion in static electricity.

Materials required: Four balloons, four equal-length strings, and a piece of wool.

Procedure: (Note: the activity would best work in cold dry surroundings). 1. Inflate all the balloons and tie their openings tightly to separate strings. 2. Take two balloons and rub them against wool. Release the balloons holding them with the strings. What do you see? You will see that the balloons move away from each other, i.e., *they repel*.

3. Now take the other set of two balloons. Rub one against wool and the other against your hair, and now bring the balloons close to each other holding them with their strings. What do you notice this time? You will see that this time the two balloons stick to one another, i.e., *they attract*.

Conclusion: We conclude that when objects are rubbed against one another, forces of attraction as well as repulsion are produced.

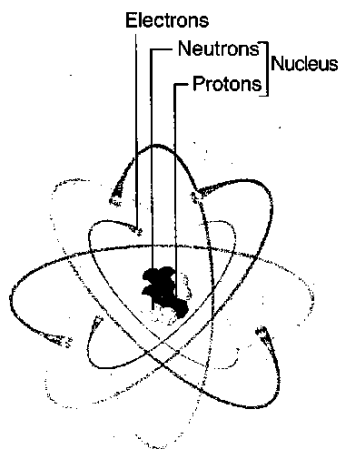


Fig. 6.1 Structure of an atom

Origin of charges

We have just seen that when an object is rubbed against another object, some electric charge develops in it due to which it either attracts or repels the other object. Where do these charges come from? Electric charges are actually present inside atoms. We know that matter and everything around us is made up of atoms. An atom consists of three main particles: *protons (the positively-charged particles)*, *electrons (the negatively-charged particles)*, and *neutrons (neutral particles)*. Figure 6.1 shows the structure of an atom.

Under normal circumstances, the atoms in an object contain the same number of protons and electrons and hence, the body is *electrically neutral*.

An object is called *electrically charged* when the number of protons and electrons is not equal. When the number of protons exceeds the number of electrons, the object is said to be positively charged. On the other hand, when the number of electrons exceeds the number of protons, the object is said to be negatively charged.

Thus, we see that an object can have either positive charge or negative charge. When an object is charged, it exerts a force on another object. If two objects of the same type of charge (positive-positive or negative-negative) are brought close together, they repel each other, i.e., push each other away. However, if two objects having opposite charge are brought close (positive-negative or negative-positive), they attract each other, i.e., pull towards each other (Fig. 6.2).

Thus, *like charges repel each other and unlike charges attract each other*.

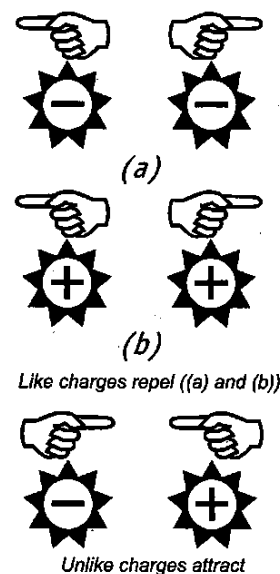


Fig. 6.2 Forces of attraction and repulsion in charges

CHARGING AN OBJECT

Let us study the methods by which an object can be charged. An object can be charged by the following methods.

1. Charging by friction;
2. Charging by conduction; and
3. Charging by induction.

Charging by friction

Let us go back to the figure on Page 91 where bits of paper were attracted to the charged plastic ruler. We saw that the ruler got charged when it was rubbed against hair. This is called *charging a body by friction or rubbing*. We must note that whenever a body is charged, it is only the electrons that move in and out of an atom leaving the body negatively or positively charged. Since the protons are tightly bound in the nucleus, they don't move. When one object (material) is rubbed against another suitable object, there is a transfer of charges between them due to friction.

Classic examples of charging by friction are:

1. Rubbing a glass rod with silk; and
2. Rubbing an ebonite rod with flannel or fur.

FACT FILE

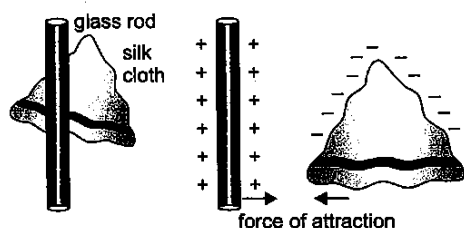
Is there any other force between a proton and an electron?

There is a gravitational force of attraction between a proton and an electron in addition to the electrostatic force of attraction. But, the gravitational force is so weak that it can be ignored.

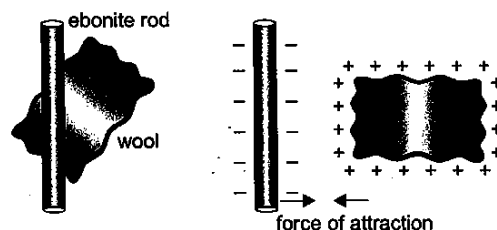
THINK QUEST

Have you ever wondered why your clothes stick to your dry body during winters and crackle when they are taken off?

(Hint: think of charging by friction.)



When a glass rod is rubbed with a silk cloth, electrons flow from the glass rod to the silk cloth. Due to the loss of electrons, the *glass rod acquires a positive charge*; on the other hand, due to excess of electrons, the *silk cloth acquires a negative charge*. Since they acquire opposite charges, they attract each other.



When an ebonite rod is rubbed with wool, electrons flow from the wool to the ebonite rod. Due to the excess of electrons, the *ebonite rod acquires a negative charge*; on the other hand, due to loss of electrons, the *wool acquires a positive charge*. Here also, since they acquire opposite charges, they attract each other.

If you bring the charged glass rod and ebonite rod close to one another, what do you find? You will find that they will be attracted towards one another. Can you tell why?

Charging by conduction

In addition to charging an object by friction, it can also be charged by touching it to an electrically charged object. *The process of charging an uncharged object by touching it to an electrically charged object is called charging by conduction.*

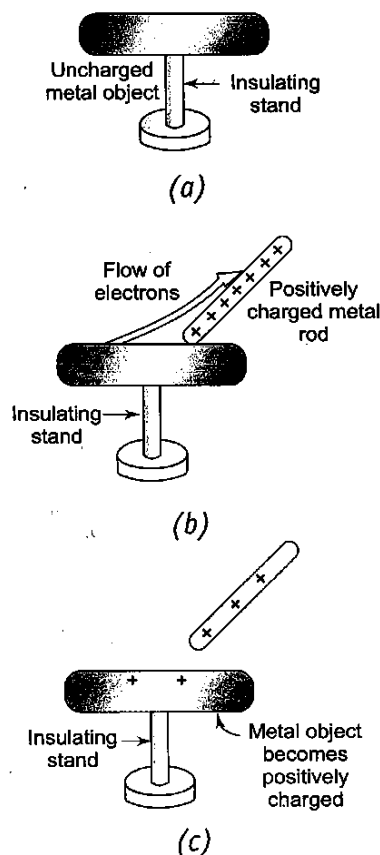


Fig. 6.3 Charging an object by conduction

We know that a charged object contains an excess of either protons or electrons. An object with an excess of electrons will be negatively charged, and the one with an excess of protons will be positively charged. What happens when these two are, one by one, brought in contact with an uncharged object?

A positively charged object has a deficiency of electrons. When such an object is brought close to an uncharged (neutral) object, the electrons flow from the uncharged object to the positively charged object [Fig. 6.3 (b)]. Due to the loss of electrons, the uncharged object gets positively charged, and the charged object becomes less positive.

On the other hand, if a negatively charged object (having an excess of electrons) is brought in contact with an uncharged object, the excess electrons from the charged object flow to the uncharged object. Due to the gain of electrons, the uncharged object becomes negatively charged, and the charged object becomes less negative.

Remember that if the object that is to be charged is a good conductor of electricity, the charge spreads to all parts of its

surface. But if it is an insulator, the charges remain at the place where the contact is made.

Charging by induction

In this method, no physical contact between the charged and the uncharged object is needed. Just bringing a charged object close to an uncharged object, without physical contact, produces a redistribution of charges in the uncharged object. Since electrons are free to move in metals, redistribution of charges occurs easily in metals.

The method of charging an uncharged body by bringing a charged body near it (but not in contact with it) is called charging by induction.

Let us see how to give a positive charge to an uncharged metallic object. Bring a negatively-charged body close to a metal sphere, which is mounted on an insulated stand. Since like charges repel, the electrons in the metal sphere move to the other side of the sphere leaving only the positive charge near the charged rod.

Therefore, the side of the metal sphere (A) that is closer to the negatively-charged object will get positively charged, and the opposite side (B) will get negatively charged [Fig. 6.4 (a)]. Now if we touch side B momentarily with our finger, the negative charges that have accumulated there will flow to the ground through our body. Thus, the metal sphere is now left with a net positive charge [Fig. 6.4 (c)]. To impart a negative charge to an uncharged object, we follow the same method described above, but by bringing a positively charged object near the uncharged object.

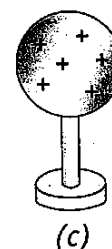
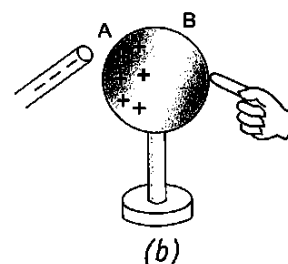
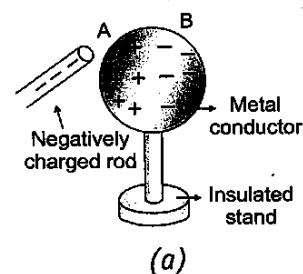


Fig. 6.4 Charging an object by induction

Table 6.1 Differences between charging by conduction and induction

<i>Charging by conduction</i>	<i>Charging by induction</i>
1. The charged object is brought in contact with the uncharged object.	1. The charged object is brought near, but not in contact with, the uncharged object.
2. Electrons flow from the charged object to the uncharged object or vice versa.	2. No electrons flow from the charged object to the uncharged object or vice versa.
3. The uncharged object gets the same kind of charge as that of the charged object.	3. The side nearer to the charged object acquires the opposite charge.
4. The charge remains on the object even after the object used for charging has been removed.	4. The charges produced on the object are temporary, unless the object is earthed.

FACT FILE

Earthing or grounding an object means connecting an object to the earth with the help of conducting wires or by physical contact. The earth is considered to be a huge reservoir of electrons. Depending upon the charge on the object, the earth provides or accepts electrons from a charged object connected to it.

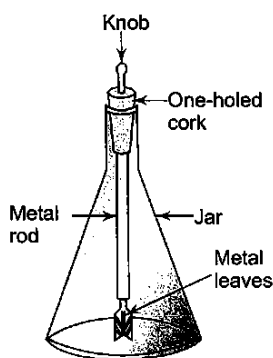


Fig. 6.5 An electrostatics jar

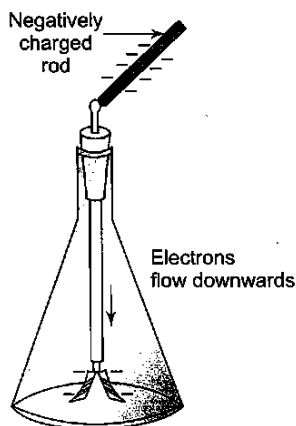


Fig. 6.6 Charging an electrostatics jar by conduction

After charging an uncharged object with any of the above methods, how do we know that the object has actually been charged or not and what charge has it got? For this, we use a device called an *electroscope*.

ELECTROSCOPE

An electrostatics jar is a device used for detecting the presence of very weak electrical charges and for determining whether that charge is positive or negative.

It consists of a glass vessel or a jar fitted with an insulating cork through which a metallic (mainly brass) rod passes. The lower end of the rod carries two thin metallic leaves hanging parallel to each other. At the upper end of the rod is a metallic (brass) knob. This glass jar is kept on a wooden base. When the knob is charged, the charge travels through the metal rod to the leaves (Fig. 6.5).

Since the two leaves get the same charge (positive or negative charge) they repel each other and therefore, diverge. The magnitude of their divergence determines the magnitude of the charge.

The early electroscopes used gold leaves and so these were called *gold leaf electroscopes* (GLEs). These electroscopes are fairly sensitive (you can rub a plastic comb to your hair, and the electrostatics jar can detect the charge created). Since the gold leaves are inside a glass jar, they are protected from stray breeze and also from human touch. This is important since the gold leaf is extremely thin and delicate.

Let us now see how an electrostatics jar can be charged.

To charge an electrostatics jar (GLE) by conduction: We know that when an ebonite rod is rubbed with wool, it gets negatively charged. When this negatively-charged ebonite rod is brought in contact with the knob of an uncharged electrostatics jar, the excess electrons from the rod flow to the uncharged electrostatics jar. As a result, the electrostatics jar gets negatively charged (Fig. 6.6). The leaves of the electrostatics jar are seen diverging because they get negatively charged (*remember, like charges repel*).

To charge the electrostatics jar positive, a glass rod rubbed with silk must be brought in contact with the electrostatics jar. Here, the electrons flow from the electrostatics jar to the positively-charged glass rod leaving the electrostatics jar positively charged. Thus, we see

that *charging an electroscope by conduction (contact) leaves the electroscope with a residual charge IDENTICAL to that of the charging rod.*

To charge an electroscope by induction: When a GLE is charged by induction, the *electroscope gets a charge OPPOSITE to that of the charged object.* Let us see how. When we bring a negatively charged ebonite rod close to an uncharged electroscope (not touching the two), the electrons on the knob get repelled towards the leaves leaving the knob positively charged. As a result, the leaves of the electroscopes develop negative charge and diverge. If the knob of the electroscope is touched or earthed, in the presence of the charged rod, the free electrons from the leaves escape to the earth via our body, and the leaves collapse. Now, if we remove our finger and then the charged rod from the electroscope, the positive charge (on the knob) gets equally distributed over the leaves and the leaves again diverge. To charge a GLE negative, the same procedure is applied but this time a glass rod rubbed with silk, which is positively charged, is used.

A GLE can be used to detect and identify the nature of (determine the kind of charge) charge on the body.

To detect whether an object is charged or not, bring the object near or in contact with an uncharged electroscope. If the leaves of the electroscope diverge, then we can say that the object is charged. In order to determine the nature of the charge, a charged electroscope is used. Let us take a negatively charged electroscope, which has excess of electrons. If a negatively-charged object is brought near the knob of this electroscope, free electrons are repelled from the knob into the leaves. As the number of electrons on the leaves increases, the divergence between the leaves also increases (as they repel more). Thus, the increase in the divergence of the leaves proves that the body is negatively charged.

On the other hand, if a charged body is brought near the knob of a negatively-charged electroscope and if the divergence between the leaves decreases, then the charge on the body is positive.

While studying the working and uses of a GLE, did you notice that the rod and the knob of the electroscope are made of a metal, like brass? Can you tell why this is so? Because electric charge can pass through *conductors*, like metals (brass, silver, copper, etc.) but not through *insulators*, like rubber and wood. The human body can also conduct charge to some extent. That is why the electroscope's leaves collapse when we touch its knob.

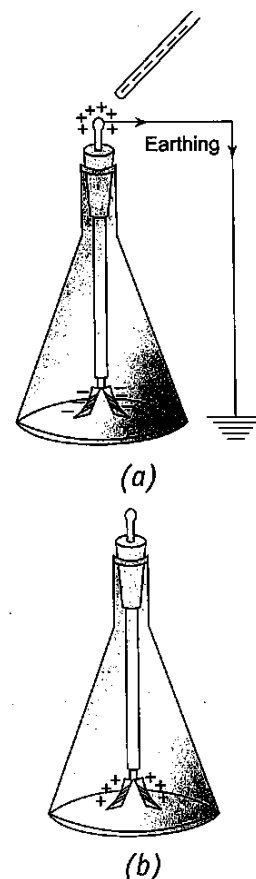


Fig. 6.7 Charging an electroscope by induction

FACT FILE

If two insulated metal spheres A and B are kept in contact and a charged body is kept nearby, the one closer to the charged body (A) develops an opposite charge and the other (B) develops same charge as the charged body. Now, if they are separated in the presence of the charged body, they will each be equal and oppositely charged, and the charged rod retains the same charge it had initially.

FACT FILE

The rubbing motion of the fuel in the fuel tank charges the truck; thus, making it inflammable and dangerous. Therefore, a conducting wire is hung from the bottom of the truck (touching the ground) to allow a safe discharge.

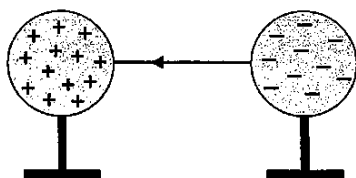


Fig. 6.8 Flow of electrons from lower potential to higher potential between two conductors

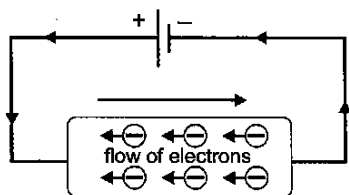


Fig. 6.9 Flow of conventional current

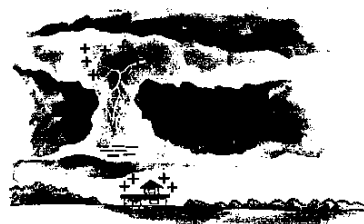


Fig. 6.10 A charged cloud

So far in this chapter we have learnt that static electricity arises due to the development of charge on an object. We know that the flow of charge (electrons) from one point to another is called electric current. But what determines the flow of these charges?

Flow of charge—electric current

You have learnt in class 7 that when there is a potential difference between the ends of a conductor, electrons flow through it. You also know that when a charged metal is kept in contact with a neutral body, electrons flow from the one which has excess of electrons to the other. This means that when we charge a conductor, we are raising or lowering its potential. A neutral body is considered to be at a zero potential.

Since positively charged bodies are considered to be at a higher potential and negatively charged bodies at lower potential, electrons flow from lower potential to higher potential when two charged bodies are connected.

This electron flow is momentary and stops when both the bodies acquire the same charge (same potential). So, to have a continuous flow of electrons through a conductor, we connect a cell which maintains a constant potential difference. The end of the conductor connected to the negative terminal of a cell is at lower potential and the end connected to positive terminal is at higher potential. Although electrons flow from a lower to a higher potential, it was earlier believed that positive charges flowed from a higher to a lower potential. This is called *conventional current*. However, we see that the flow of electrons is opposite to the conventional current. But unless otherwise mentioned, the direction of electric current is still taken in the direction of conventional current.

Static charges in the atmosphere

Do you know that even our atmosphere has static electric charges? You might have seen lightning during thunderstorms. Can you explain how it occurs? Lightning occurs because of a massive electric charge flowing from cloud to cloud, from one part of the cloud to another, or from a cloud to the ground.

While there are several theories, the exact mechanism of lightning generation during a thunderstorm is not known. One thing that scientists are sure of is that thunderclouds carry electric charges and these charges separate out within the cloud. The lower portion of a cloud generally carries negative charges and the

upper portion carries positive charges. These charges keep building up inside the clouds, but they cannot flow from one cloud to another or to the ground because the air between them acts as an insulator.

But when a huge amount of charge builds up, the insulating property of the air breaks down. As a result, an electric discharge takes place between two oppositely-charged clouds, or between a charged cloud and the surface of the earth. This causes the flash of lightning that we see in the sky. The enormous amount of heat produced causes the air to expand and vibrate suddenly, which is the cause of thunder that sometimes accompanies lightning. Since, *lightning is a high-energy electric discharge*, it could be very dangerous. Therefore, we must know how to protect ourselves during a thunderstorm. Some safety measures that could be taken are as follows:

1. DO NOT take shelter under a tree. If the tree gets struck by lightning, it could catch fire and cause great harm to you.
2. Try to go indoors for shelter. You can even take shelter inside a car or a bigger vehicle, like a truck.
3. DO NOT run across a large open field, or high ground.
4. If you can't find a safe place, squat down in a low-lying place.

In order to protect buildings from the damaging effects of lightning, *lightning conductors* are used.

Lightning conductors

A lightning conductor is a long pointed metal rod fixed on top of the building to be protected. The lower end of the lightning conductor is connected to a metal plate, which is buried deep inside the earth with the help of a conducting wire.

Imagine a negatively-charged cloud coming over a building. By induction, a positive charge is induced on the conductor. Since there is a force of attraction between the positive and the negative charge, the negative charge will get discharged (flow) through the lightning conductor to the ground, without damaging the building.

An **electric spark** is an electric discharge through air, vacuum, or any other gas. You would have seen these sparks at electric switches. Switch off all the lights at night and then observe the fan switch closely when you turn on/off the fan. You will most likely see a small flash of light. This is an electric spark due to the charges jumping across

the small gap formed when the switch is being turned on. Lightning is one example of a huge electric spark in the atmosphere.

FACT FILE



Benjamin Franklin carried out the famous 'kite experiment' to show that lightning was an electrical phenomenon. He flew a kite in the sky on a stormy day and tied the other end of the kite string to a metal key. Lightning struck and got transferred to the metal key. Franklin was fortunate enough to have been saved from a massive electric shock.

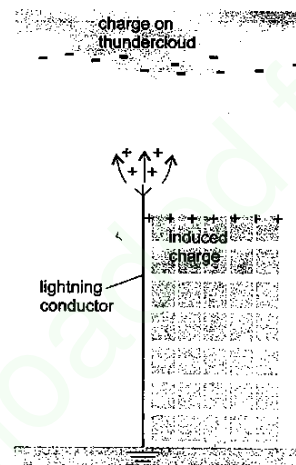


Fig. 6.11 A lightning conductor



KEYWORDS

Static electricity Study of charges that are separated from a neutral atom and their effects

Charging by conduction Charging an uncharged body by touching it to an electrically charged object

Charging by induction Charging an uncharged object by bringing a charged body near it

Electroscope Device used for detecting and identifying the nature of charge

Lightning Formed by the discharge of electric charges in the atmosphere

Lightning conductor Protects the buildings from the harmful effects of lightning

SUMMARY

- Static electricity is the study of charges, which have been separated from a neutral body and its effects.
- Like charges repel and unlike charges attract.
- A body can be charged by friction, conduction, or induction.
- The process of charging an uncharged body by touching it to an electrically-charged object is called charging by conduction. By conduction you charge the body with the similar kind of charge.
- The method of charging an uncharged body by bringing a charged body near it is called charging by induction. By induction you can charge a body with opposite kind of charge to that of the charging body.
- An electroscope is a device used for detecting the presence of electric charge and also to determine the kind of charge.
- Lightning conductor protects the building from the effects of lightning.

EXERCISES

I. Review questions

A. Choose the correct answer

1. You can remove an electron from a/an by rubbing.
(a) conductor (b) insulator (c) metal (d) conductor or an insulator
2. When a positively charged rod is kept in contact with an insulated metal, the electrons move from the
(a) metal to the rod (b) rod to the metal
(c) metal to the ground (d) ground to the metal
3. If a body touching the disc of an uncharged GLE makes its leaves , we can say that the body is charged.
(a) collapse (b) diverge (c) neither diverge nor collapse (d) fall off
4. To charge an electroscope negatively by induction, we need charged body.
(a) a positively (b) a negatively (c) either positive or negative (d) an un
5. The lower end of the lightning conductor is connected to a metal plate and
(a) to the building (b) deep inside the earth
(c) to the cloud (d) to the ceiling

B. Fill in the blanks

1. An electron has (no/negative) charge, whereas a neutron has (no/negative) charge.
2. Like charges (attract/repel), and unlike charges (attract/repel).
3. When a glass rod is rubbed with silk, glass rod acquires (positive/negative) charge.
4. (Electrogram/Electroscope) is used to detect the presence of charge on a body.
5. When a negatively-charged body touches the knob of a negatively-charged GLE, its leaves (diverge/collapse).
6. Conventional current is considered to be the flow of (electrons/protons).

C. Correct the statements that are false

1. An uncharged atom has an equal number of neutrons and protons.
2. When you rub an insulator with a suitable material, protons move from one body to the other.
3. If a body is positively charged, and then grounded, electrons flow from the earth to the charged body.
4. The charge given by conduction is of the same kind as that on the body used for charging.

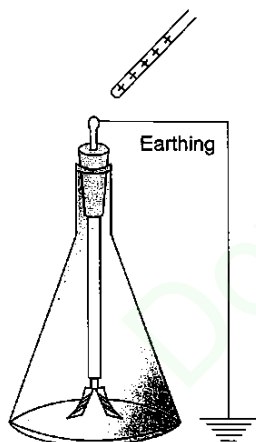
D. Answer the following questions

1. What are the charges associated with protons, electrons, and neutrons?
2. What are the three methods in which a body can be charged?
3. How can you charge a body by conduction?
4. How can you charge a body by induction?
5. Draw a diagram of a gold leaf electroscope and label its parts.
6. How does a GLE detect whether there is charge on a body or not?
7. Explain how do you charge a GLE by induction?
8. How does a GLE find the nature of charge on a body?
9. How does lightning strike the ground?
10. How does a lightning conductor protect buildings from lightning?

II. Skill-based questions

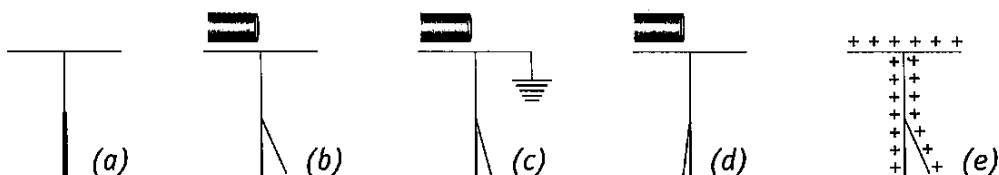


- E. Mark the charges on the knob, leaves, and the direction of electron flow through the grounding wire

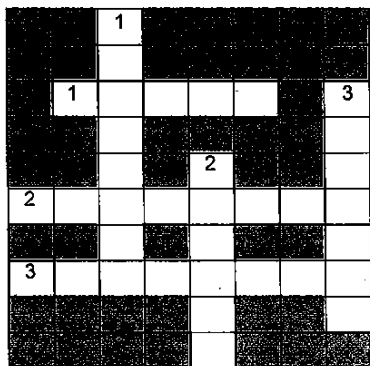




F. Rohit wants to charge a GLE positively by induction. Figure (e) shows the result. Complete figures (a) to (d) by putting the correct charges on the rod and the electroscope



III. Fun time



Across

1. The knob of the electroscope is made of this metal (5)
2. Charging a body by rubbing (8)
3. Electrons carry this charge (8)

Down

1. Connecting a body to the ground (8)
2. Electricity due to the development of charges (8)
3. This generally accompanies lightning (7)

PROJECT IDEA

- **Make your own improvised electroscope.** Take a glass bottle with a wide mouth. Take a piece of cork that fits into the mouth of the bottle. Make a tiny hole in the cork through which a copper wire is passed. On one end of the copper wire attach a small metallic plate. At the other end, make a small loop or hook. Cut a thin strip of aluminium foil. Place the strip on the hook of the copper wire. Now put the cork in place and close the mouth of the bottle tightly. Your electroscope is ready. Now bring a charged ebonite or glass rod and charge your electroscope by conduction and induction. Observe the divergence of the aluminium leaves.

TEACHER'S NOTES

- The importance of a lightning conductor in preventing damage to buildings could be explained by taking students to a nearby area where tall buildings are provided with lightning conductors.

Website references

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