3 Electricity and Circuits

"Rubbing one body against another produce a buildup of opposite kinds of charges on each other. The buildup of electrical charges on an object is called static electricity."

1. Introduction

Have you ever seen lightning flash during a storm? Have you watched a cricket game under the bright flash lights? If so, then you have seen electricity in action. Electricity powers lights, ovens and computers. Electricity makes your clothes stick together when you take them out of the clothes dryer.

The what is electricity? That's not so easy to answer. Electricity is the result of electrical charges. To understand electrical charge, we have to start with matter. Everything around us is made up of matter. This book is made of matter. You are made of matter. Like colour or hardness, **electrical charge is a property of matter**.

2. Positive and negative charges

There are two types of electrical charges. These charges are called positive and negative charges. You cannot see or feel electrical charge the way you can see colour or feel hardness. However, you can observe how charges interact with each other.

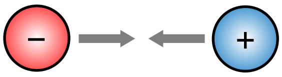
A positive charge and a negative charge attract, or pull each other. Positive charges repel, or push away each other. Negative charges repel each other too.

Electric charge is a scalar quantity i.e., it has only magnitude, does not have any direction. It is measured in a unit 'Coulomb'.

SPOT LIGHT

- Like charges repel each other while unlike charges attract each other.

(a) Like charges repel each other



(b) Unlike charges attract each other

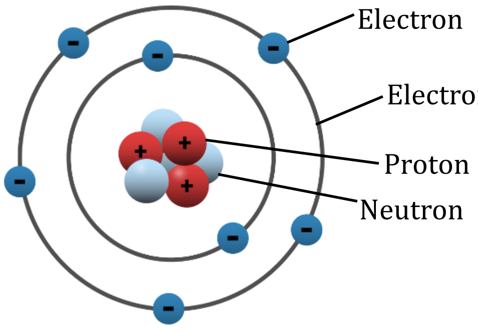
Interaction of two electric charges with each other.

Charges add up

Matter consists of tiny particles called atoms. **Atoms contain particles called protons, neutrons, and electrons**. Protons and electrons have electric charge, and neutrons have no electric charge. Protons have positive electric charge and electrons have negative electric charge. The amount of positive charge on a proton equals the amount of negative charge on an electron. If an atom contains equal number of protons and electrons, the positive and negative charges cancel out and the atom has no net electric charge. Objects with no net charge are said to be electrically neutral.

Over 2,500 years ago, Greeks discovered that amber rubbed with fur attracted feathers.

Now, in an atom, protons and neutrons reside inside the nucleus while electrons moves around the nucleus. It is only the 'transfer of electrons' which makes an atom or a matter positive or negative.



An atom

- An atom becomes negatively charged when it gains extra electrons. If an atom loses electrons it becomes positively charged. An electrically charged atom is called **ion**.

Quick Tips

★ Just like likes poles repel and unlike poles attract each other, charges also have similar nature.

3. Static electricity

Suppose you rub a balloon with a woolen cloth. Negative charges (electrons) would move from the wool to the balloon. This would produce a buildup of negative charges in the balloon and positive charges on woolen cloth. A buildup means that it has more of one kind of charge than the other. The buildup gives the balloon an overall negative charge. The wool would be left with a buildup of positive charges.

> The word 'electricity' comes from the ancient Greek word for amber which is 'electrum' or 'elektron'.
>
> SPOT LIGHT

The buildup of electrical charges on an object is called **static electricity**. The term static electricity is used because here the charges accumulated on the surfaces of the materials are at rest.

You know that charged particles can move between objects when the objects touch each other. Even more charged particles can move when objects rub against each other. Rubbing objects together causes them to touch in more places. Rubbing produces a larger buildup of charge.

The static electricity developed on the surfaces of the bodies when rubbed against each other is also called **frictional electricity**.

Building Concepts 1

Have you ever taken clinging clothes from a clothes dryer? Why this happens? How can this cling can be reduced or avoided?

Electrons move between clothes in a dryer.

A positively charged sock will stick to a negatively charged T-shirt.

Explanation

In a cloth dryer, when clothes are rubbed against each other, some clothes gain electrons while some clothes loose electrons. Thus, they get oppositely charged. Since opposite (or unlike) charges attract each other, the clothes cling to one another. This tendency for clothes to stick (cling) to other clothes because of development of opposite charges on them is called static cling.

To reduce or avoid the static cling of clothes, put the synthetic materials and the natural materials for separate drying. Combining synthetic materials in the dryer, such as nylon, often leads to static cling with natural materials, such as cotton. Also, do not dry clothes for too long as over drying also leads to static cling.

Active Physics 1

1. Take an inflated balloon. Now, rub the inflated balloon back and forth across your hair for some time. Now, separate the balloon from your hair.

Active Physics 1

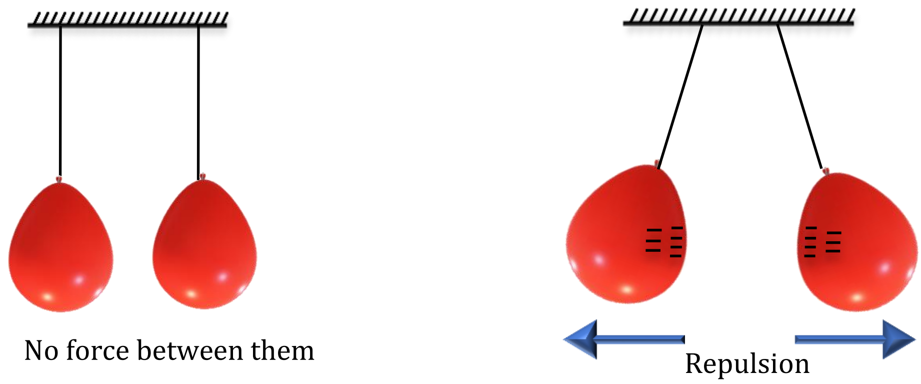
2. Now bring the balloon near your hair. You will find that the balloon is attracted to your hair (see figure).

Conclusion : When two bodies are rubbed against each other, they get charged. The charges on them are opposite in nature i.e., one becomes negative while other becomes positive. Oppositely charged particles or unlike charges attract each other.

Active Physics 2

1. Inflate two balloons. Hang them in such a way that they do not touch each other [see figure (a)].

2. Rub both the balloons one by one with a woollen cloth. Now, release them. You will observe that the balloons repel each other.



(a) Initially no charge is present on each balloon.

(b) Both acquire like charges on rubbing with woollen cloth.

Active Physics 2

Conclusion : Since balloons are made of same material (rubber) and they are rubbed against the same material (wool), both acquire similar charges (like charges). In this case, both become negative. Here, we observe that they repel each other thus, we can conclude that **'like charges repel each other'**.

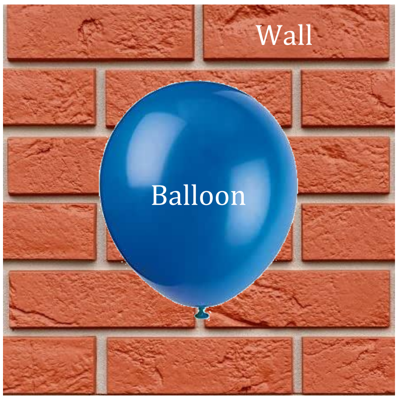
List of objects acquiring two kinds of charges on rubbing

S.no	Positive charge	Negative charge
1.	Glass rod	Silk
2.	Woollen cloth or fur	Ebonite, Amber, Rubber
3.	Woollen cloth	Plastic
4.	Dry hair	Plastic Comb

Active Physics 3

1. Take an inflated balloon. Now, rub the inflated balloon back and forth across your hair for some time. Now, separate the balloon from your hair.
2. Now, touch the rubbed balloon to a dry wall. The rubbed balloon will stick to the wall, often for hours (see figure).

(a) Balloon rubbed against dry hair



(b) Charged balloon and uncharged wall attract each other

Active Physics 3

Conclusion : When two bodies are rubbed against each other, they get charged. Here, the balloon get charged as it is rubbed against the dry hair. Note that the wall is not charged as we have not rubbed the balloon or any other thing against the wall. Thus, we can say a charged object can get attracted towards an uncharged object.

Building Concepts 2

Why a negatively charged balloon sticks to the uncharged wall?

Explanation

When you hold a negatively charged balloon near a wall, it repels the negative charges (electrons) present in the wall.

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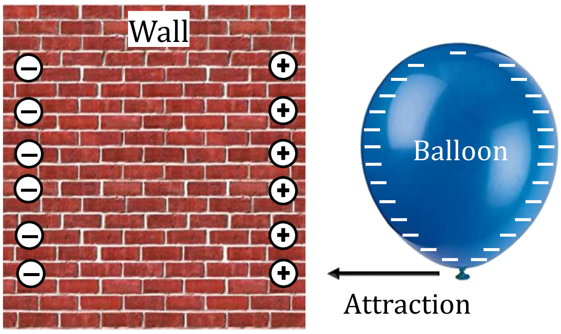
This makes the wall near the balloon positive. As we know, negative charge and positive charge attract each other, the negative charged balloon attracts the positively charged portion of the wall. This pull makes the balloon "stick" to the wall (see figure).



Building concepts 2

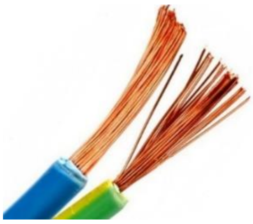
☞ A charged body is attracted towards an uncharged body by process called induction. The process of charging an uncharged body from a charged body without touching them together is called **induction**.

4. Conductors and insulators

You know that you can get a shock from a metal doorknob. If you touch the wooden door first, you can avoid that surprising shock. This is because the metal is a conductor while wood is an insulator.

Conductors are materials that allow charges to flow through them easily. In other words 'materials which allow electric current to pass through them are conductors of electricity'. Charges move quickly from your body into the doorknob. You feel the fast discharge as a shock. Metals such as copper and silver are good conductors of electricity.

☞ Metals are good conductor as they have large number of free electrons. These electrons act as if they no longer belong to any one atom, but to the metal as a whole; consequently, they move freely throughout the piece of metal.



(a) Copper wire

(b) Silver wire

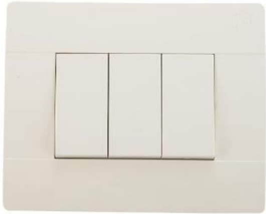
(c) Iron nail

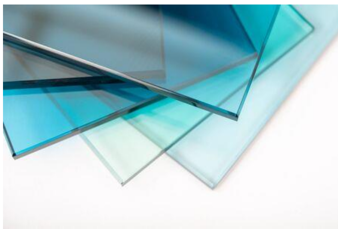
Conductors of electricity

Insulators are materials that do not allow charges to flow through them easily. In other words 'materials which do not allow electric current to pass through them are insulators of electricity'. When you touch the wooden door, charges move slowly onto the surface of the door. Because this discharge is slow, you don't feel it. Rubber, plastic, glass and air are also good insulators.

☞ Insulators have electrons that are tightly bound to the nucleus and are not free to travel within the substance i.e., they have few or negligible number of free electrons. Thus, they do not conduct electricity.


(a) Rubber stopper


(b) Plastic switch board


(c) Glass

Insulators of electricity

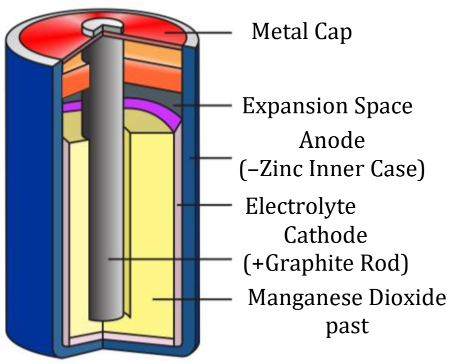
Conductors and insulators are equally important for us. Switches, electrical plugs and sockets are made of conductors. On the other hand, insulators like rubber and plastics are used for covering electrical wires, plug tops, switches and other parts of electrical appliances which people might touch.

Human body is also a conductor. That is why, sometimes you can get a shock when you touch a charged body. Carelessness in handling electricity and electric devices can cause severe injuries and sometimes even death.

Danger signs displayed on poles, electric substations and many other places to warn people that electricity can be dangerous if not handled properly.

5. Electric cell

A torch is sometimes used for providing light. A torch has a bulb that lights up when it is switched on. Electricity to the bulb in a torch is provided by the electric cell. Electric cells are also used in alarm clocks, wristwatches, transistor radios, cameras and many other devices. You might have noticed that it has a small metal cap on one side and a metal disc on the other side (see figure). You may have noticed a positive (+) sign and a negative (–) sign marked on the electric cell. The metal cap is the positive terminal of the electric cell. The metal disc is the negative terminal. All electric cells have two terminals; a positive terminal and a negative terminal. A commonly used dry cell that is used in torches, wall clocks, TV remotes, etc. is shown in figure.



Dry cell

An electric cell produces electricity from the chemicals stored inside it. That is, in an electric cell **'chemical energy is converted into electric energy'**. When the chemicals in the electric cell are used up, the electric cell stops producing electricity. Then, the electric cell has to be replaced with a new one.

A combination of two or more cell is called a **battery**. There are many kinds of cells or batteries. They come in different sizes and shapes. Batteries are often called power source or voltage sources [see figure].

Batteries or cells come in different shapes and sizes.

6. Electric current

When you are in the dark, a flashlight (torch) can be used to provide light. A flow of electricity causes the bulb to light.

☞ A flow of electrons through a conductor is called an **electric current**. Electric current is measured in a unit called **Ampere**.

The amount of electric current that can flow through a circuit depends on (i) voltage (ii) resistance.

Voltage

Voltage is the strength of a power source. A power source with more voltage can produce more electric current. Voltage is measured in a unit called **Volt**. For example, a dry cell has 1.5 volts. In India, the electricity which we get from a power plant has a voltage of 220 volts.

Quick Tips

★ Current does not exist without voltage.

Resistance

Resistance is the property of a substance to oppose or slow down electric current. Increasing the resistance of a circuit decreases the flow of electrical charges through it. Resistance allows electrical energy to be changed into other forms of energy, such as light and heat. Resistance is measured in a unit called **Ohm**.

Copper wires are good conductors. They have very little resistance, so they can carry a great deal of electric current. Rubber is an insulator that has a large amount of resistance. It is difficult to make any electric current flow through rubber.

7. Circuits

To make an electric current, you need a path to carry the current. The path along which electric current flows is called a **circuit**.

☞ A circuit is formed when an electric current passes through an unbroken path of conductors. A simple circuit has three basic parts. It has a **power source**, such as a battery. This powers a **load**, such as a lamp, a computer, television, mobile phone, etc. **Connectors**, such as wires, carry electrical charges between the power source and the load.

Do You Remember ?

★ Connecting wires, switches etc. have insulators on them so that we don't get electric shock. So definition of insulators has to be remembered.

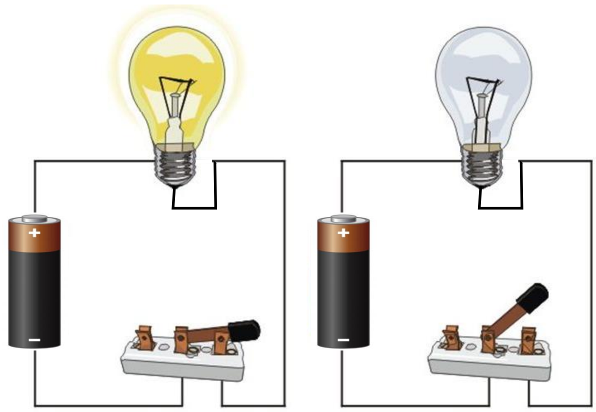
Switch

Many circuits have a switch. A **switch** turns electric current on and off. The lights in your classroom are controlled by a switch.

A switch is a device that can open or close the path of electric current. When the switch is closed (i.e., on), the voltage of the battery pushes on the electrons in the circuit. This causes electrons to move. Protons feel a force in the opposite direction. Protons, however, are not free to move as they reside in the nucleus of an atom.

Open and closed circuits

To keep charges moving, the circuit cannot have any breaks. A complete, unbroken circuit is called a **closed circuit**. If the circuit has any breaks or openings, it is called an **open circuit**. Electric current cannot flow in an open circuit.



(a) Closed circuit (b) Open circuit

Open and closed circuits

Building Concepts 3

When a light bulb burns out (get fused), it stops emitting light. Why?

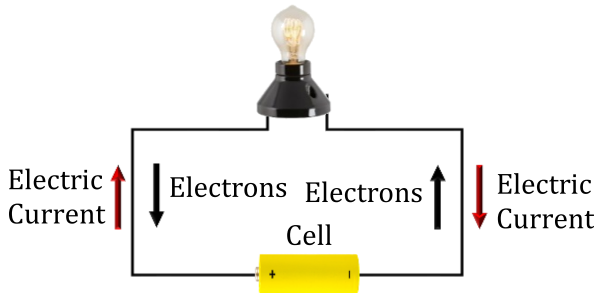
Explanation

When a light bulb burns out, it makes an open circuit. This happens because a wire inside the bulb breaks in two. The circuit no longer has a complete path, so electric current cannot flow through it. Hence, it does not emit light.

Conventional direction of current

Electric current is always said to flow from the positive terminal to the negative terminal in a circuit. This is called **conventional current**. This way of describing the movement of electric current originated before scientists fully understood electricity. However, it is still the way used to describe how circuit operates.

In a circuit, the movement of negatively charged electrons is from negative terminal to the positive terminal. Thus, we can say, **direction of movement of electrons is opposite to the direction of electric current.**



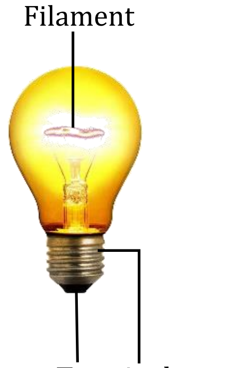
Showing direction of flow of electrons and the electric current

1. Which material would you suggest for outer body of a switch?

2. If electrons are moving towards north, then what is the direction of electric current?

8. Torch bulb

A torch bulb or any other electric bulb has an outer case of glass that is fixed on a metallic base (see figure). Inside the bulb, there is a thin wire that gives off light which is called the **filament** of the bulb. The filament is fixed to two thicker wires, which also provide support to it. One of these thick wires is connected to the metal case at the base of the bulb. The other thick wire is connected to the metal tip at the centre of the base. The base of the bulb and the metal tip of the base are the two terminals of the bulb. These two terminals are fixed in such a way that they do not touch each other.



An electric bulb

☞ The filament generally made of tungsten metal of an electric bulb has high resistance. When an electric current flows to the filament, electrical energy converts into heat energy. Then, the heated filament produces light.

Both the electric cell and the bulb have two terminals each. Why do they have these two terminals?

Explanation

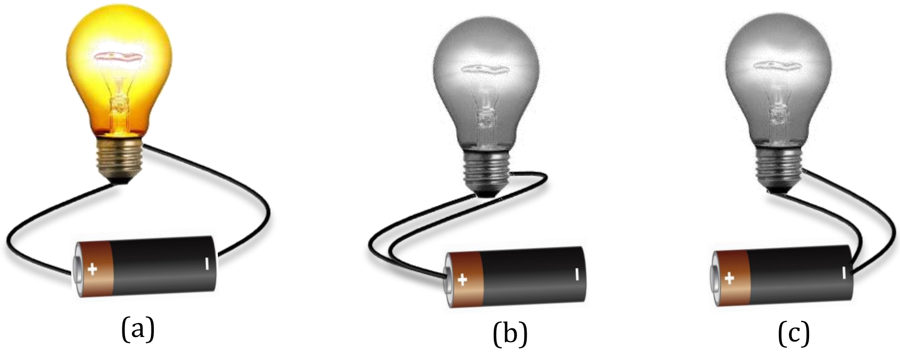
The two terminals are required in electric cell or a bulb or any other electric device to make the circuit complete. From one terminal, current enters into the device while the current leaves from the other terminal of the device. Also, one terminal must be positive while other terminal must be negative.

Be Alert !

★ An electric bulb don't have fixed polarity on its terminals. When it is connected to a cell or battery its's terminals becomes positive and negative.

Active Physics 4

1. Join a torch bulb to an electric cell using connecting wire as shown in figure (a), figure (b) and figure (c). For each arrangement, find out whether the bulb glows or not.
2. In the arrangement shown in figure (a), the bulb glows as its terminals are joined with the different terminals of the cell as a result of which one end becomes positive and the other end becomes negative. In the arrangements shown in figure (b) and figure (c), the bulb does not glow. This is because in these arrangements, the terminals of the bulb are joined with the same terminal of the cell. As a result, the terminals of the bulb are either negative or positive and thus, no current flows through it.

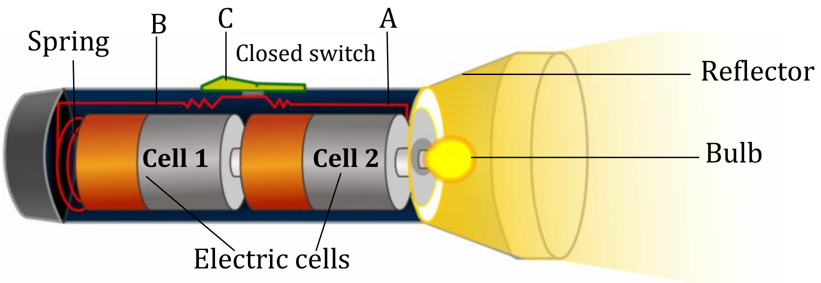


Active Physics 4

9. Electric circuit of a torch (flashlight)

The negative terminal of the cell 1 presses against the spring at the base of the torch. Positive terminal of the cell 1 touches the negative terminal of the cell 2. The positive terminal of the cell 2 presses against the metal tip at the base of the bulb.

There are three metal strips. Strip A is connected with the metal case of the bulb, strip B is connected with the spring and strip C is a part of the switch. While metal strips A and B are fixed, strip C can be pressed and made to slide. When you press the switch, the strip C touches strips A and B and the circuit is complete. Then current flows in the circuit and makes the bulb glow.



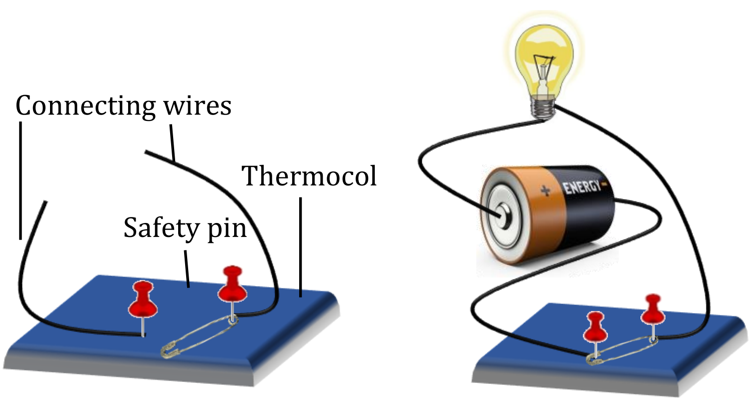
A torch or flashlight

Be Alert !

★ In the diagram of a torch, always connect positive terminal of cell 1 to the negative terminal of cell to and positive terminal of cell 2 with bulbs terminal to complete the circuits

Active Physics 5

1. Take two drawing pins, a safety pin, two connecting wires and a small sheet of thermocol. Insert a drawing pin into the ring of the safety pin and fix it on the thermocol sheet [see figure (a)]. Make sure that the safety pin can be rotated freely.



(a) Drawing pins (b) Switch is 'on', bulb glows. (c) Switch is 'off', bulb does not glow.

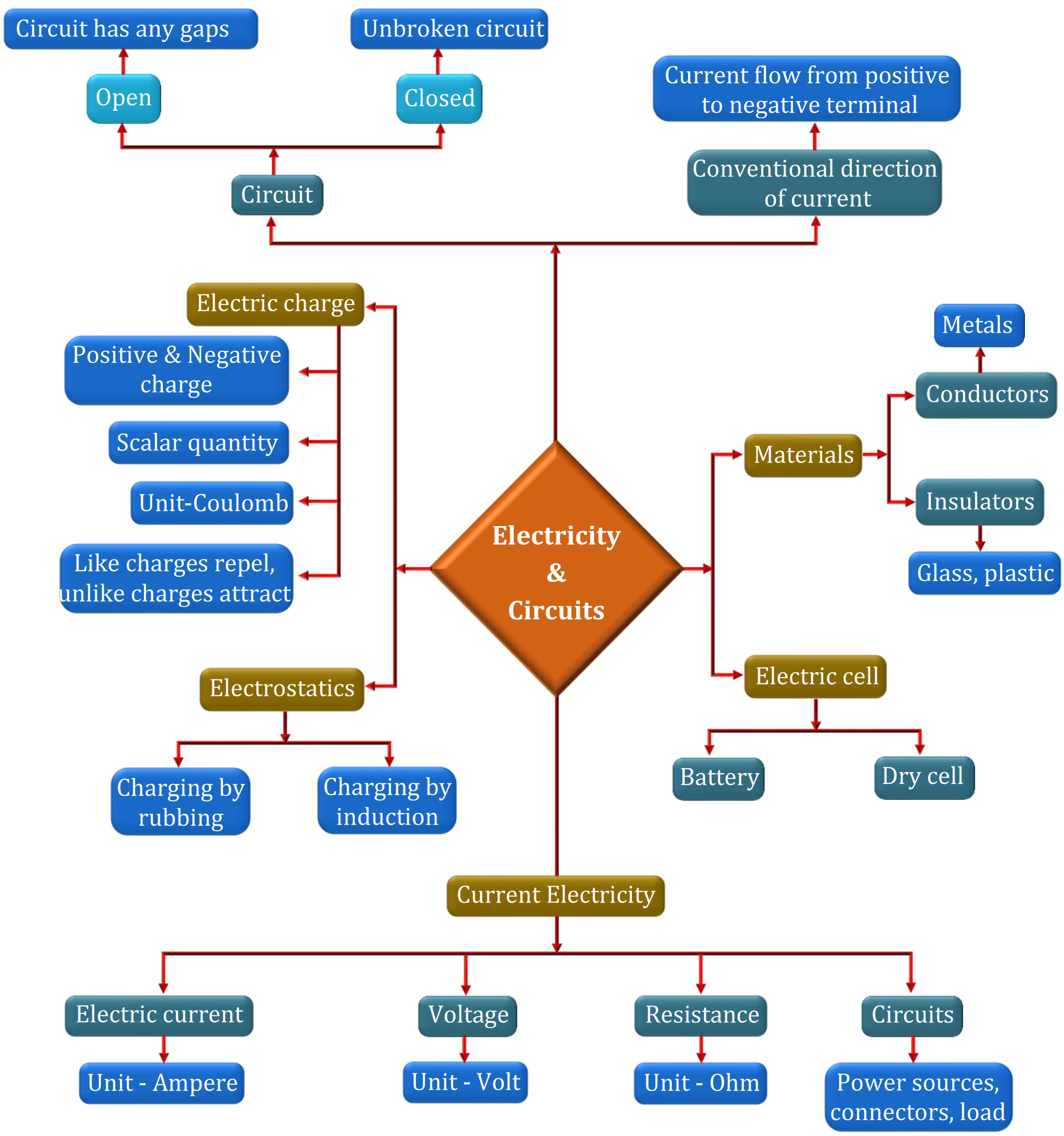
Active Physics 5

2. Now, fix the other drawing pin on the thermocol sheet in a way that the free end of the safety pin can touch it. This arrangement acts as a switch.
3. Now, make a circuit by connecting an electric cell and a bulb with this switch. Rotate the safety pin so that its free end touches the other drawing pin [see figure (b)]. The bulb glows in this case. The safety pin covers the gap between the drawing pins when you make it touch two of them. In this position the switch is said to be 'on'.
4. Now, move the safety pin away [see figure (c)]. The bulb stops glowing in this case. Here, the safety pin is not in touch with the other drawing pin. The circuit is not complete as there is a gap between the two drawing pins. In this position, the switch is said to be 'off'.

Check your Answers 1

1. Since we always touch the outer body of a switch to open or close the switch, the material used should be an insulator so that we do not get an electric shock. Thus, a material like rubber or plastic should be used for making the outer body of a switch.
2. The direction of electric current is opposite to the direction of movement of electrons. It is given that the direction of movement of electrons is towards north, thus, the direction of flow of electric current is towards south.

Concept Map


Circuit has any gaps
Unbroken circuit
Open
Closed
Current flow from positive to negative terminal
Circuit
Conventional direction of current
Electric charge
Positive & Negative charge
Scalar quantity
Unit-Coulomb
Like charges repel, unlike charges attract
Metals
Conductors
Materials
Insulators
Glass, plastic
Electricity & Circuits
Electrostatics
Electric cell
Charging by rubbing
Charging by induction
Battery
Dry cell
Current Electricity
Electric current
Voltage
Resistance
Circuits
Unit - Ampere
Unit - Volt
Unit - Ohm
Power sources, connectors, load

Some basic terms

1. **Magnitude** - size of some quantity.
2. **Inflated** - Increases in size when filled with air.
3. **Conventional** - based on or in accordance with what is practiced generally.
4. **Cling -** to hold on tightly to somebody/something.
5. **Amber -** when rubbed, amber becomes negatively charged and attracts lightweight particles such as pieces of straw, fluff, or dried leaves.
6. **Socket -** a place in a wall or extension board where a piece of electrical equipment can be **connect**ed to the electricity supply.
7. **Polarity** - it is an entity contains two distinct and opposite poles that can either attract or repel each other.
8. **Connectors** - parts or devices used for electrically connecting or disconnecting circuits.
9. **Buildup** - an increase of something over a period.
10. **Static -** "Static" means stationary or at rest.