JSR IAS ACADEMY

GENERAL SCIENCE
PHYSICS

Electricity - III

Transfer of Charges

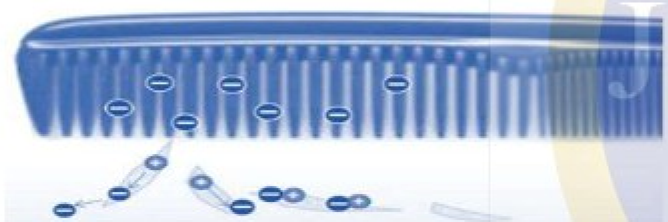
The substance which **gains electrons become negatively charged** and the **substance which looses electrons becomes positively charged.**

Transfer of charges takes place in the following three ways.

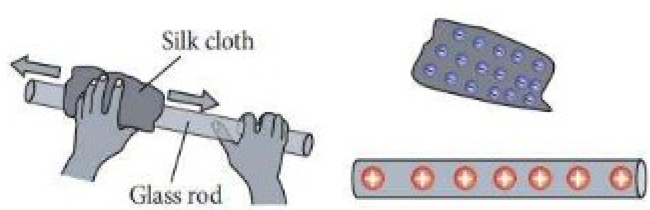
1. Transfer by Friction
2. Transfer by Conduction
3. Transfer by Induction

Transfer by Friction

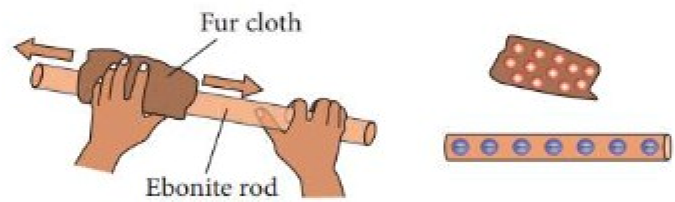
- Comb rubbed with hair gains electrons from the hair and becomes negatively charged.
- When a piece of paper is teared into bits, positive and negative charges are present at the edges of the bits.
- Negative charges in the comb attract positive charges in the bits. So, the paper bits are moving towards the comb.
- If the hair is wet, the friction between the hair and the comb reduces which will reduce the number of electrons transferring from hair to comb.



- When a glass rod is rubbed with a silk cloth the free electrons in the glass rod are transferred to silk cloth.
- Since the glass rod looses electrons, it has a deficiency of electrons and hence acquires positive charge.
- But, the silk cloth has excess of electrons. So, it becomes negatively charged.



- When an ebonite rod (rod made by vulcanized rubber) is rubbed with fur, the fur transfers electrons to the ebonite rod because the electrons in the outermost orbit of the atoms in fur are loosely bound as compared to the ebonite rod.
- The ebonite rod which has excess electrons becomes negatively charged and the fur which has deficiency of electrons is positively charged.



Transfer by Conduction

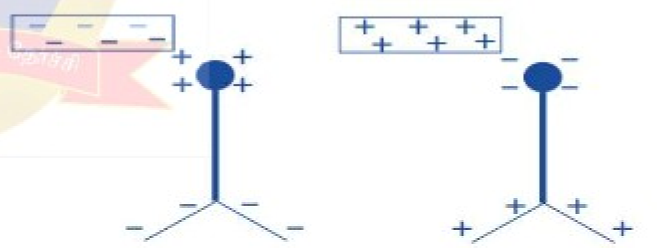
charges can be transferred to on object by bringing it in contact with a charged body.

Transfer by Induction

The process of charging an uncharged body by bringing a charged body near to it but without touching it is called induction.

Electroscope

- An electroscope is a scientific instrument **used to detect the presence of electric charge on a body.**
- In the year **1600, British physician William Gilbert invented the first electroscope.**
- It is the **first electrical instrument**.
- There are **two types of electroscope**: **pith-ball electroscope and goldleaf electroscope.**
- It works on the **principle** that **like charges repel each other.**



The first electroscope developed in 1600 by William Gilbert was called versorium. The versorium was simply a metal needle allowed to pivot freely on a pedestal. The metal would be attracted to charged bodies brought near.

Gold leaf electroscope

- The gold-leaf electroscope was developed in **1787** by a **British scientist named Abraham Bennet**.

- **Gold and silver are used in electroscope** because they are the best conductors of electric current.
- Structure of Electroscope It is made up of a glass jar.
- A vertical brass rod is inserted into the jar through a cork.
- The top of the brass rod has a horizontal brass rod or a brass disc.
- Two gold leaves are suspended from the brass rod inside the jar.

Working of Electroscope

- When the brass disc of the electroscope is touched by a charged object, electric charge gets transferred to the gold leaf through the rod.
- This results in the gold leaves moving away from each other.
- This happens because both the leaves have similar charges.

Charging

- Transfer of charge from one object to another is called charging.
- In case of the gold leaves charge is transferred through the brass rods.

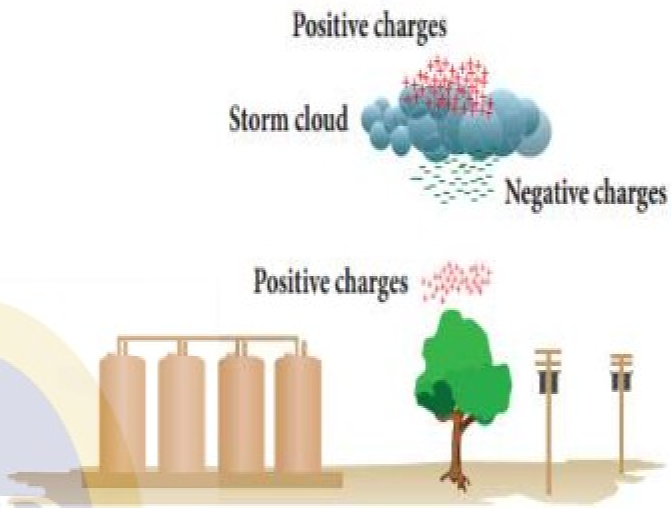
Electrical Discharge

- The gold leaves resume their normal position after some time. This happens because they lose their charge. This process is called electrical discharge.
- The gold leaves would also be discharged when someone touches the brass rod with bare hands.

Figure 2.8 Gold leaf electroscope

Lightning and Thunder

- Lightning is another example of discharge that takes place in clouds.
- Lightning is produced by discharge of electricity from cloud to cloud or from cloud to ground.
- During thunderstorm air is moving upward rapidly.
- This air which moves rapidly, carries small ice crystals upward.
- At the same time, small water drops move downward.
- When they collide, ice crystals become positively charged and move upward and the water drops become negatively charged and move downward.
- So the upper part of the cloud is positively charged and the lower part of the cloud is negatively charged.
- When they come into contact, electrons in the water drops are attracted by the positive charges in the ice crystals.



- Sometimes the lower part of the cloud which is negatively charged comes into contact with the positive charges accumulated near the mountains, trees and even people on the earth.
- This discharge produces lot of heat and sparks that results in what we see as lightning.
- Huge quantities of electricity are discharged in lightning flashes and temperatures of over 30,000°C or more can be reached.
- This extreme heating causes the air to expand explosively fast and then they contract.
- This expansion and contraction create a shock wave that turns into a booming sound wave, known as thunder.

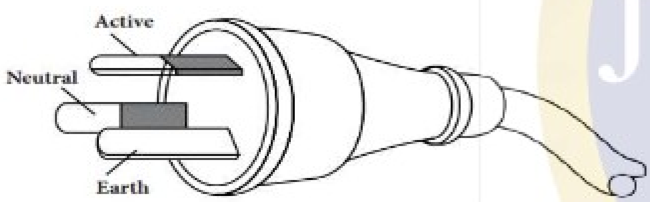
DO YOU KNOW? Lightning's extreme heat will vaporize the water inside a tree, creating steam that may burn out the tree.

- Sometimes lightning may be seen before the thunder is heard.
- This is because the distance between the clouds and the surface is very long and the speed of light is much faster than the speed of sound.

DO YOU KNOW? During lightning and thunder, we should avoid standing in ground and open spaces. You should make yourself as small as possible by squating. It is however safe to stay inside a car because the car acts as a shield and protects us from the electric field generated by the storm.

Earthing

- A safety measure devised to **prevent people from getting shocked** if the insulation inside electrical devices fails is called Earthing.
- Electrical earthing can be defined as the **process of transferring the discharge of electrical energy directly to the Earth with the help of lowresistance wire.**
- Usually an electric appliance such as a heater, an iron box, etc. are fitted with three wires namely **live, neutral and earth.**
- The earth wire is **connected to the metallic body of the appliance.**
- This is done to avoid accidental shock.



- Suppose due to some defect, the insulation of the live wire inside an electric iron is burnt then the live wire may touch the metallic body of the iron.
- The Earth, being a good conductor of electricity, acts as a convenient path for the flow of electric current that leaks out from the insulation.

Lightning Arresters

- Lightning arrestor is a device **used to protect buildings from the effects of lightning.**
- Lightning conductor consists of a metallic lightning rod that remains in air at the top of the building.
- Major portion of the metal rod and copper cable are installed in the walls during its construction.
- The other end of the rod is placed deep into the soil.
- When lightning falls, it is attracted by the metallic rods at the top of the building.
- The rod provides easy route for the transfer of electric charge to the ground.
- In the absence of lightning arrestors, lightning will fall on the building and the building will be damaged.

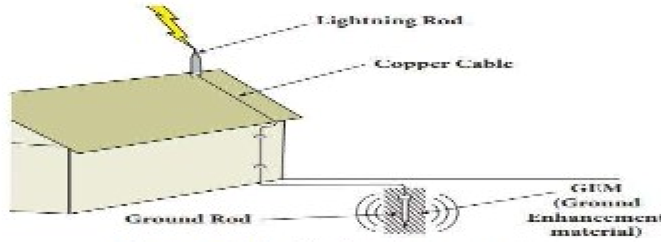


Figure 2.11 Lightning arresters

DO YOU KNOW? The electric eel is a species of fish which can give electric shocks of upto six hundred fifty watts of electricity. But if the eel repeatedly shocks, its electric organs become completely discharged. Then a person can touch it without being shocked.

Dangers of electricity and precautions

Damaged insulation:

Do **not touch the bare wire**. **Use safety glows** and **stand on insulating stool or rubber slippers** while handling electricity.

Overload of power sockets:

Do **not connect too many electrical devices to a single electrical socket.**

Inappropriate use of electrical appliances:

Always use the electrical appliances according to the power rating of the device like ac point, TV point, microwave oven point etc.

Environment with moisture and dampness:

Keep the place, where there is electricity, out of moisture and wetness as it will lead to leakage of electric current.

DO YOU KNOW? Resistance of a dry human body is about 1,00,000 ohm. Because of the presence of water in our body the resistance is reduced to few hundred ohm. Thus, a normal human body is a good conductor of electricity. Hence, precautions are required while doing electrical work.

Beyond the reach of children:

The electrical sockets are to be kept away from the reach of little children who do not know the dangers of electricity.

Safety measures to safeguard a person from electric shock

I. Switch off the power supply.

II. Remove the connection from the switch.

III. Push him away using non - conducing materials.

IV. Give him first aid and take him to the nearest health centre.

OHM'S LAW

A German physicist, **Georg Simon Ohm** established the relation between the potential difference and current, which is known as Ohm's Law.

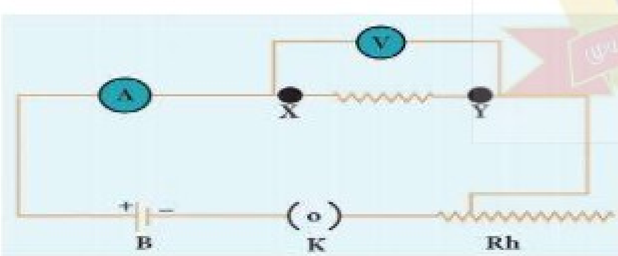


Figure 4.4 Electric circuit to understand Ohm's law

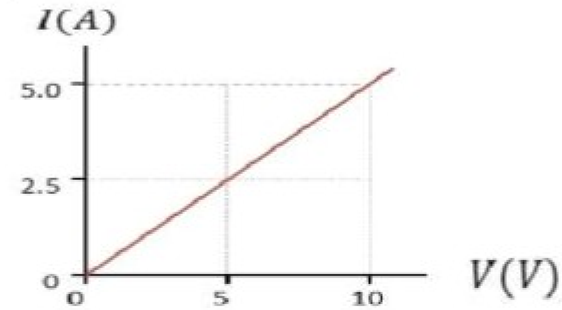
According to Ohm's law, **at a constant temperature**, the **steady current 'I' flowing through a conductor is directly proportional to the potential difference 'V' between the two ends of the conductor.**

I α V. Hence, I/V= constant.

The value of this proportionality constant is **1/R**

Hence, **I = (1/R)V**

V = IR



Calculate the resistance of a conductor through which a current of 2 A passes, when the potential difference between its ends is 30 V.

Solution:

Current through the conductor I = 2 A, Potential Difference V = 30 V

From Ohm's Law: $R = \frac{V}{I}$.

Therefore, $R = \frac{30}{2} = 15\ \Omega$

Three resistors of resistances 5 ohm, 3 ohm and 2 ohm are connected in series with 10 V battery. Calculate their effective resistance and the current flowing through the circuit.

Solution:

$R_1 = 5\ \Omega$, $R_2 = 3\ \Omega$, $R_3 = 2\ \Omega$, V = 10 V

$R_s = R_1 + R_2 + R_3$, $R_s = 5 + 3 + 2 = 10$, hence $R_s = 10\ \Omega$

The current, $I = \frac{V}{R_s} = \frac{10}{10} = 1$ A

1. Two bulbs are having the ratings as 60 W, 220 V and 40 W, 220 V respectively. Which one has a greater resistance?

Solution:

Electric power $P = \frac{V^2}{R}$

For the same value of V, R is inversely proportional to P.

Therefore, lesser the power, greater the resistance

Hence, the bulb with 40 W, 220 V rating has a greater resistance.

2. Calculate the current and the resistance of a 100 W, 200 V electric bulb in an electric circuit.

Solution:

Power P = 100 W and Voltage V = 200 V

Power P = V I

So, Current, $I = \frac{P}{V} = \frac{100}{20} = 0.5$ A

Resistance, $R = \frac{V}{I} = \frac{200}{0.5} = 400\ \Omega$

Joule's Law of Heating

The work done in moving the charge **Q** across the ends of the resistor with a potential difference of **V** is **VQ.**

This **energy spent by the source gets dissipated in the resistor as heat.**

Thus, the heat produced in the resistor is:

H = W = VQ

Q = I/t.

H = (VI)/t

From Ohm's Law, **V = I R.**

Hence, you have **$H = I^2/Rt$** .This is known as Joule's law of heating.

Joule's law of heating states that the heat produced in any resistor is:

- directly proportional to the square of the current passing through the resistor.
- directly proportional to the resistance of the resistor.
- directly proportional to the time for which the current is passing through the resistor.

Applications of Heating Effect

1. Electric Heating Device:

In these appliances **Nichrome**, which is an alloy of **Nickel and Chromium** is used as the heating element. Why? Because:

(i) it has high resistivity,
(ii) it has a high melting point,
(iii) it is not easily oxidized.

2. Fuse Wire:

When a large current passes through the circuit, the fuse wire melts due to Joule's heating effect and hence the circuit gets disconnected.

3. Filament in bulbs:

The filament is **made up ofa material whose melting point is very high.**

When **current passes through this wire**, heat is produced in the filament. When the **filament is heated, it glows and gives out light. Tungsten** is the commonly used material to make the filament in bulbs.

An electric heater of resistance 5 Ω is connected to an electric source. If a current of 6 A flows through the heater, then find the amount of heat produced in 5 minutes.

Solution:

Given resistance R = 5 Ω, Current I = 6 A, Time t = 5 minutes = 5 × 60 s = 300 s

Amount of heat produced, $H = I^2Rt$, $H = 6^2 \times 5 \times 300$. Hence, H = 54000 J

ELECTRIC POWER

- In general, power is defined as the rate of doing work or rate of spending energy.
- Similarly, the electric power is defined as the rate of consumption of electrical energy.

Suppose a current 'I' flows through a conductor of resistance 'R' for a time 't', then the potential difference across the two ends of the conductor is 'V'.

The work done 'W' is **W = VIt**, Power **P = V I**

Unit of Electric Power

The SI unit of electric power is **watt.**

When a current of 1 ampere passes across the ends of a conductor, which is at a potential difference of 1 volt, then the electric power is

DOMESTIC ELECTRIC CIRCUITS

After the main switch, these wires are connected to live wires of two separate circuits.

- one circuit is of a **5 A rating**, which is used to run the electric appliances with a lower power rating, such as **tube lights, bulbs and fans.**
- The other circuit is of a **15 A rating,** which is used to run electric appliances with a high power rating, such as **air-conditioners, refrigerators, electric iron and heaters.**

DO YOU KNOW? **HORSE POWER:**
The horse power (hp) is a unit in the foot-pound-second (fps) or English system, sometimes used to express the electric power. It is equal to 746 watt.

Consumption of electrical energy

Electricity is consumed both in houses and industries. Consumption of electricity is based on two factors:

(i) Amount of electric power
(ii) Duration of usage.

For example, if 100 watt of electric power is consumed for two hours, then the power consumed is $100 \times 2 = 200$ watt hour.

its SI unit is **watt second**. In practice, a larger unit of electrical energy is needed. This larger unit is **kilowatt hour (kWh).**

1 kWh = 1000 watt hour = $1000 \times (60 \times 60)$ watt second **= 3.6×10^6 J**

LED BULB

- An LED bulb is a **semiconductor device that emits visible light** when an electric current passes through it.
- The colour of the emitted light will depend on the type of materials used.
- With the help of the chemical compounds **like Gallium Arsenide and Gallium Phosphide,** the manufacturer can produce LED bulbs that radiates **red, green, yellow** and **orange colours.**

Seven Segment Display

- A 'Seven Segment Display' is the display device used to give an output in the form of **numbers or text.**

DO YOU KNOW? In India, domestic circuits are supplied with an alternating current of potential 220/230V and frequency 50 Hz. In countries like USA and UK, domestic circuits are supplied with an alternating current of potential 110/120 V and frequency 60 Hz.

- It consists of 7 segments of LEDs in the form of the digit 8.
- These **seven LEDs** are named as **a, b, c, d, e, f and g** .An extra **8th LED** is used to display a **dot**

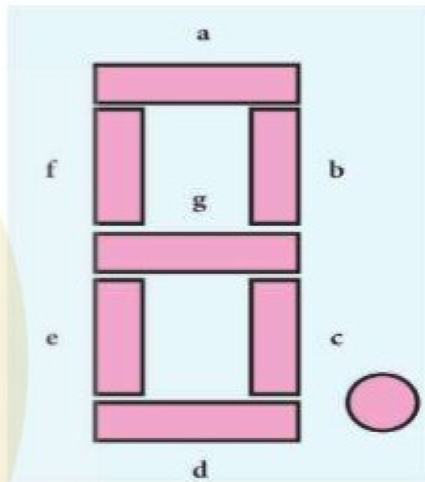


Figure 4.12 Seven segment display

Merits of a LED bulb

1. As there is no filament, there is no loss of energy in the form of heat. It is cooler than the incandescent bulb.

2. In comparison with the fluorescent light, the LED bulbs have significantly low power requirement.

3. It is not harmful to the environment.

4. A wide range of colours is possible here.

5. It is cost-efficient and energy efficient.

6. Mercury and other toxic materials are not required. One way of overcoming the energy crisis is to use more LED bulbs.

LED TELEVISION

- An LED TV is actually an LCD TV (Liquid Crystal Display) with LED display.

- An LED display uses LEDs for backlight and an array of LEDs act as pixels.
- LEDs emitting white light are used in monochrome (black and white) TV;
- Red, Green and Blue (RGB) LEDs are used in colour television.
- The **first LED television** screen was developed by James **P. Mitchell in 1977.**
- It was a monochromatic display. But, after about three decades, in **2009, SONY introduced** the first commercial LED Television.

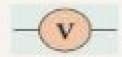
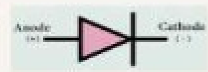
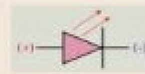
Advantages of LED television

- It has brighter picture quality.
- It is thinner in size.
- It uses less power and consumes very less energy.
- Its life span is more.
- It is more reliable.

The Major Electric power stations in Tamilnadu:

- Thermal stations (Neyveli in Cuddalore District, Ennore in Thiruvallur District),
- Hydel power stations (Mettur in Salem District, Papanasam in Tirunelveli District),
- Atomic power stations (Kalpakkam in Kanchipuram District, Koodankulam in Tirunelveli District),
- Wind mills (Aralvaimozhi in Kanyakumari District Kayatharu in Tirunelveli District).

Symbol	Device	Symbol	Device	Symbol	Device
or	Switch		Wires joined	— G — or`	galvanometer
	Cell		Wires crossed	A	ammeter
	Battery		Fixed resistor	V	Voltmeter
	D .c . power` supply		variable resistor` (rheostat)		Two-way switch
	A.c. power supply		fuse		Earth connector
	Light bulb		Coil of wire		capacitor
	Potentiometer		transformer		thermistor
	light-depemdent resistor (LDR)		Semiconductor diode		bell

COMPONENT	USE OF THE COMPONENT	SYMBOL USED
Resistor	Used to fix the magnitude of the current through a circuit	
Variable resistor or Rheostat	Used to select the magnitude of the current through a circuit.	
Ammeter	Used to measure the current.	
Voltmeter	Used to measure the potential difference.	
Galvanometer	Used to indicate the direction of current.	
A diode	A diode has various uses, which you will study in higher classes.	
Light Emitting Diode (LED)	A LED has various uses which you will study in higher classes.	
Ground connection	Used to provide protection to the electrical components. It also serves as a reference point to measure the electric potential.